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Studies on the Biology of Kansas Cicadidæ.*

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INTRODUCTION.

MY interest in cicadas was first aroused by the sport involved in collecting them. Almost anyone enjoys hunting quails with a good gun and a good dog. How much more interesting it is to hunt cicadas; detect them by their song from the myriad other noises of a summer day; locate the singer by his repeated cries; and then, either take him with a net or shoot him with a rifle in true sportsman style. The cunning of the hunter also is necessary in taking cicadas. A hurried movement or a broken twig, and the song stops as though broken in the middle, or with a wild squawk and a buzz of wings the game is off to safer quarters.

Interest in the biology of these insects grew quite naturally from collecting them. Occasionally females were found ovipositing. From nests of eggs collected it was noted that the eggs of some

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species did not hatch till the following year, and fortunately, unlike the seventeen-year cicada, the eggs remained in good condition though the limbs bearing them were cut from the trees. From material thus kept in the laboratory, two new species of nest parasites were found. Thus at every turn new and interesting facts in their biology were brought to light.

The following pages are an attempt to set down the interesting things noted about some of our common Kansas cicadas. Fifteen species have been studied representing five of the seven genera occurring in the state.

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NATURE OF THE PROBLEM.

Since the seventeen-year cicada, *Magicicada septendecim* (Linn.), the only one whose life history is known, spends such a long period of time underground, it is natural that particular attention should be given to the developmental stage of these insects. Questions present themselves as to the number of instars; morphological characteristics of each stage; the duration of each stadium; the food pref-

erences of the nymphs of each species, if any; and the mysteries of their movements underground. Along with so many things of interest occurring beneath the soil, the emerging nymph introduces us to many new problems in the open air.

The oft repeated statement that the adult cicada takes no food makes the question of feeding very interesting. Mating and oviposition are other absorbing problems. Where do they lay their eggs? In what type of substance—green or dead tissue—trees or grasses? What kind of nests do they make? Do they fill them with secretions of any kind? Does the dying of the twig kill the eggs? What egg parasites are to be found? A multitude of questions arise in this part of the life cycle. The hatching of the eggs, effect of heat and moisture upon hatching, the making of underground cells by the nymph, all present phenomena of intense interest.

The above queries introduce some unique difficulties. First of all, the only species about which anything is known takes seventeen years to go through its life cycle—an astounding length of time when one considers the attempt to work out the life history in detail. The unity of opinion among writers, however, that perhaps most or even all other species pass through their life cycle within a year, or two years at most, gave some encouragement in attacking the problem.

Another difficulty presented itself by the occurrence of different species emerging in localities many miles apart. For example, the past year (1926), three species were studied in Scott county, Kansas, and three others in Cherokee county, Kansas. The two localities are 400 miles apart by automobile. Then, too, some of these species are tree-loving forms, and he who would learn of them must simulate the habits of a squirrel. The shyness, also, which most members of this family exhibit to the would-be observer is no small obstacle in obtaining worth-while data.

Attempts to collect nymphs in the field for study and rearing purposes have been made. These have proved feasible only under the most favorable conditions. Comparatively speaking, very few individuals of a species emerge each year in a given area. This fact is indicative of the number of nymphs in the ground at a given place and time. For example, let us suppose that in a ten-acre wood lot with a tree on every ten-foot square there is a pair of cicadas in each tree. No one would gainsay that the lot would be a perfect din with their songs, but if one were to try to find the nymphs of

one of these pairs in the ground beneath their tree, tons of earth would have to be moved and examined. This has been, indeed, a very real difficulty.

To add to the problem the nymphs of different species within the genus are so nearly alike that only where one species occurs alone in a locality can one be reasonably sure of the identity of his material, even if he finds it.

The problem is rendered still longer and more difficult by the fact that the adults occur but once a year, and then, in the case of most species, for only a few weeks. In addition, a large brood of a given species may occur in a certain locality only once in a number of years. Nevertheless the problem has become increasingly interesting, and plans have been made to continue the studies until many of the still unsolved mysteries have been answered.

HISTORICAL SKETCH.

Long before the science of biology was born, before the habit of attempting to explain the phenomena of life had been developed, even before written records were kept of the thoughts of peoples, the cicada had attracted attention. The Egyptians gave images of this insect a religious significance. The ancient Greeks used them as a symbol of music and also as a decoration on coins. The Athenians fashioned golden ornaments in their likeness. In early writings they were often praised because of their song, and even held as almost sacred. For centuries the Chinese have used them for their coloring matter and medicinal properties. A common superstition has been handed down that the "W" in the cicada's wing forecasts war.

Records of many primitive peoples of the past and of the present show cicadas have been used as articles of food. Aristotle wrote that they were most edible just before emergence. Reaumur tells us that some of the ancients ate the males before mating and the females after. He adds that they liked the eggs of cicadas as the French people of his day enjoyed crab eggs.

The first record of the seventeen-year cicada (the most famous member of the family) was made by Oldenberg, London, in 1660, in a paper entitled "Some Observations of Swarms of Strange Insects and the Mischief Done by Them." Unfortunately, in this paper he used the term locusts, thus confusing them from the first with the true locusts (Locustidæ). The brood which he had observed occurred in 1634 in New England. The colonists reported

at this time that the American Indians used the cicadas as food; and Andreas Sandel, of Philadelphia, in 1715 again mentioned this custom. The first serious attempt at a study of the biology and morphology of cicadas, however, was made by Reaumur in 1740. So accurate was his description of the sound-producing organs of the male that it is still used. He also made observations of the nests and the eggs. He observed nest parasites, but made no attempt to preserve them or place them systematically other than to say they were ichneumonids. He tried to hatch the cicada eggs, but had very poor results, failing to observe the process.

A century later Fabre, in his pleasing way, recorded many interesting observations on the oviposition, the nests, the eggs and the hatching of the cicada. He observed hymenopterous parasites laying eggs in the cicada nests but, like Reaumur, failed to record the identity of them. He even made an attempt to rear the nymphs in a bowl of growing wheat and heather. This, however, failed and he decided that, while it might be done, it was not worth the effort.

Little has been done on the biology of cicadas other than *Magicicada septendecim* (Linn.) since the time of Fabre. A detailed account of the work done on this species has been given by Marlatt, United States Department of Agriculture Bureau of Entomology Bulletin No. 71, 1907, and it will not be repeated here. Even with this species, where thousands of eggs were available, rearings in captivity failed. The data obtained were gained from digging under trees where nymphs were known to have hatched in great numbers. Numerous writers have recorded notes on the oviposition, nests, eggs, etc., of some local species. Several have studied in greater or lesser detail the song and song habits of various forms. Snodgrass and Muir have done valuable morphological work on the group. It is hoped the following notes will be of interest and will add to what is already known of the biology of the cicadas.

TECHNIQUE OF DETERMINING THE LIFE HISTORY.

A STUDY OF BROODS.

Former writers have suggested that the life histories of cicadas might be indicated fairly accurately from the occurrence of extra large broods in the field. For the past four years records have been kept on broods of different species in several localities. Whenever a large brood of any species has been observed, the locality and species have been noted, and also the time of year of the occurrence

of the largest numbers of individuals. Then other notes have been taken of the habits of the particular species, such as the time of day the males usually sing, the type of hosts the females use for oviposition, and the general appearance of the plants bearing nests. The localities have been visited each succeeding year as nearly as possible at the time most favorable for finding the maximum number of individuals. The comparative numbers of some of the small, grass-loving species are estimated by collecting them by sweeping; the large, wary species are usually judged by the song of the males. Something of the size of the brood may be ascertained by the number of cast nymphal skins on the ground or vegetation and by the oviposition marks left by the females where these are of a nature to be seen easily. Both details are accurate indicators, since one readily learns to distinguish between new and old. Cast nymphal skins will remain recognizable for a year, but they show the effect of weather and would not be mistaken for newly cast ones. The nests may be more confusing, but a little study soon renders one quite expert in judging their age, and there is always the test of cutting into the nest to find it either empty or containing live eggs.

Size of broods can be expressed only in relative terms, as large or small, and the judgment of the observer would be valuable in proportion to his experience. So far no method of measure has been devised.

Observations indicate that a great many records of a species should be obtained, and perhaps records in more than one locality, before an accurate conjecture could be made as to the length of its life history. This is due not only to the fact that there might be more than one large brood in a locality, but also to the many factors which might cause a large brood to be diminished to a small one.

DATA ON LIFE HISTORY BY DIGGING NYMPHS IN THE FIELD.

Hope was entertained that a shorter and more accurate method might be found for obtaining data on the life history of cicadas by digging for nymphs in the field. Accordingly many hours have been spent in this way with gratifying success in a few instances and disappointment in many.

WHERE TO DIG. Locations were selected where a species had been known to be abundant. Often old oviposition marks determined the exact place for excavating. In timber, the north side of large trees near the trunk yielded the best results. Some locations, which might have proved fruitful, were impractical because of the rocky

nature of the soil. Digging has been delayed occasionally by prolonged drouth. Not only is the labor of digging in dry soil greater, but a much higher percentage of individuals is injured in the operation. In all cases more large nymphs were found than those of the smaller instars. This is probably due to the fact that as the nymphs increase in size their cells are more often broken open, and also to the fact that a large nymph is less apt to be overlooked. In a locality where dozens of fifth-instar nymphs were taken only two second-instar individuals were found; yet the next year many third instars were collected, indicating that they had been present the year before.

EQUIPMENT NECESSARY. A tile spade, a large bladed knife, and a pair of tweezers constitute the equipment most often used in digging for nymphs. Wide-mouthed bottles containing 70 per cent alcohol are used for preserving the material in the field. If nymphs are to be taken to the laboratory alive, suitable containers must be provided. This will be discussed in detail a little later.

METHOD OF FINDING THE NYMPHS. Large spades of dirt are cut loose and carefully lifted to a nearby natural clearing or to an artificial one made by unfolding a heavy newspaper. The sides of the excavation and of the removed lump of dirt are then examined carefully for nymphs which may have been expelled from their cells or for burrows into which the excavating has broken. When these leads have been examined and any material removed, the sod is held about a foot above the improvised worktable and gently torn to pieces. Work may be accelerated and also made more accurate by a helper carefully watching the surface of this table as the particles fall. In most soils the nymphs are readily seen because of the difference in color. As each additional spade of soil is removed, it is examined over the same place, thus soon building a small, flat-topped mound which forms a convenient worktable.

As the nymphs are discovered they may be removed to the alcohol vials by means of tweezers, but, if live specimens are to be obtained, this method of handling has proved undesirable because so many specimens are injured. Often nymphs will grasp the tweezers with their front legs and may be lifted thus to the live cage. Otherwise they should be rolled gently into the hand or lifted with the knife blade and again gently rolled from the hand or knife into the awaiting container.

In the case of the seventeen-year cicada, and occasionally with

large broods of other species, a satisfactory method is that of removing the soil above a root for a few feet, then cutting the root loose at one end and gently raising it. The largest number of nymphs will have formed cells perpendicular to and directly beneath such roots. Removing the root leaves the cells open at the top, hence easily seen.

TRANSPORTING LIVE NYMPHS. Specimens left exposed to the dry air for any considerable time are destroyed by desiccation. If numbers are confined in the same container without partitions, they mangle each other with their sharp claws. The first attempt to overcome these difficulties was to cover each specimen as found with loose earth. This relieved the above-mentioned conditions, but the nymphs were often injured by the weight of the dirt. A nymph will dig in the most compact soil, provided it is not too dry, but it finds itself at a great disadvantage in loose earth. If it cannot make the soil hold together and fashion an open space or cell, it can only flounder helplessly, bruising its soft body with the hard particles and gradually wearing away its strength.

IN MUD CELLS. Individual cells made from mud proved a safe way to transport them. A nymph so placed will ride in a car for hours uninjured provided only that the ball remains whole. A more desirable method where many nymphs were to be transported was that of placing a layer of stiff mud about one inch deep in a flat box and putting the individuals in artificial cells. As each cell was filled, it was capped with a bit of flattened mud to prevent the escape and desiccation of the occupant. Nymphs have been thus inclosed without injury for a longer period during cold weather than hot. If the container was too tightly closed, nymphs confined for many hours have been found to be suffocated. Specimens which appeared dead from suffocation have been revived by leaving them in the open air for a short time. Where they were left for hours, a wet cloth was spread over the container. Numerous nymphs, thus revived, have formed cells and apparently recovered completely.

IN LIVE CAGES. Live cages have been taken into the field and the nymphs placed in them as they were found. This has proven a most desirable way where it is possible. Live cages have the advantage over the mud cell in that the new home formed is permanent. Newly transplanted nymphs begin work on the new cell immediately if kept in a warm place.

EXAMINATION OF MATERIAL IN THE LABORATORY. Hundreds of preserved nymphs were studied in the laboratory in an attempt to determine the number of instars and the length of the life history. The nymphs of a species were first separated as to apparent size. Then each size was studied in detail under the microscope. The hard parts were measured. The number of segments of the antennæ was compared in specimens of the same size and those of other sizes. The number of setæ-bearing spines on the hind legs was compared. The development of the front femora and tarsi was studied, as to size, number of teeth in the comb, etc. The size of the wing pads, size and shape of the pronotum, the genitalia, and general and specific color changes were all noted. From all these studies it seemed impossible to decide the number of instars. Size divided them into several groups. Even measurements of the hard parts, which supposedly do not change within an instar, were found to vary. The character of the antennæ seemed to divide them into five groups, but the variation in size of other parts was so great that it was impossible to tell whether the differences were due to added age or inherent nature of the individual. So many empty shells of nymphs having large wingpads had been found in burrows in the field that it was considered these large nymphs perhaps molted once during this stage.

Accurate data now seemed to depend upon actual rearings in captivity. Since the small size of year-old nymphs hatched and reared thus far in the insectary indicated a relatively long life history for all cicadas, an attempt was made to trick nature into giving up her secret in a shorter time by simultaneous rearing of the various instars which were found in the field.

FLOWER-POT CAGES. A large number of experiments have been conducted in an attempt to determine the best types of live cages to use. Eggs have been hatched over large flower pots of perennial grass, and a year later the nymphs found by carefully tearing the dirt into fine particles. This cage has proved valuable when only growth of the nymph was desired, but it was obviously not practical for catching molts or for observing habits. To meet this need, small glass-sided cages were constructed.

SMALL GLASS-SIDED CAGES. Three sides of a wooden frame one-half to one inch deep by four inches wide by five inches long were nailed together and a 4 x 5 glass plate placed on either side of it. The sides were fastened in place by two wraps of a very fine copper

wire. Small lead lugs were numbered and tied on these wires for records.

HOST PLANTS. Since the first nymphs found in the field had been living on *Panicum virgatum,* small green sprays of this grass were dug and placed in a dozen or more of these cages with good, rich soil. The results were disappointing. This grass, divided down as small as was necessary, would not take root and grow as it should. One of two things seemed necessary. Either larger cages must be used to allow the large grass to grow, or smaller grasses or other small plants must be found on which the nymphs could live.

An attempt was first made to give the large grass room to grow, and at the same time isolate some of its roots in small amounts of soil surrounded by glass so that observations could be made without disturbing the plant or insects. Six holes were bored in the bottom of a box and small test tubes, punctured at the closed end to allow the escape of excess moisture, were inserted in these holes. Then grasses were placed in the box with a healthy root extending the length of the test tube and the tubes filled with finely sifted and sterilized earth. The nymphs were placed in the test tube, and when they had disappeared into the soil, the box was filled with more of the sterilized dirt. The soil was then moistened and the box buried in loose sand in the laboratory. Another attempt to accomplish the same result was made with glass cylinders. A smaller cylinder closed at one end was inverted in a larger cylinder. Grasses were placed in the large beaker with their roots extending around the inner cylinder. When the cage was partly filled with soil the nymphs were placed between the two glass walls. Then the space above was filled with soil. In both types of cages the nymphs and the grasses lived, but neither plan was considered a success because the thinnest film of dirt over the glass obstructed observation and to remove the film it was necessary to demolish the cage.

ANNUALS AS HOST PLANTS. At the same time the above experiments were being run, small annual grasses were being tried in the glass-sided cages described above. They grew rapidly, and nymphs placed among their roots gave every evidence of being in perfect condition. This encouraged the belief that cicada nymphs are not specific feeders, and experiments were started to determine what kind of plants would make the most ideal hosts for them. Former writers have held that nymphs probably passed the winter in a dormant state and hence could live where only annuals were avail-

able. All material, however, which was left in cages containing annuals died when the grasses ripened in the fall.

VEGETABLES AS HOSTS. A series of experiments was begun to determine, if possible, whether cicada nymphs might secure food from fresh tubers. Fifth instar *Magicicada septendecim* (Linn.) were used in the trials, with potatoes as the host.

Two methods were tried: First, a hole was made in the potato about the diameter of the cells from which the cicadas were taken. These holes were closed by small pieces of celluloid inserted through slits made in the potato. (Pl. XXXIII, Fig. 5.) Second, the cicadas were placed in artificial cells in a pan and the top of the holes capped with small potatoes.

These experiments were started on December 4, 1926, with fifteen nymphs. They were kept in the laboratory where the temperature was warm enough to allow normal activity.

RESULTS. Of the five nymphs placed inside the potatoes one died December 19, one December 20, two others were dead February 1, and the last, though still alive, was noticeably diminished in size March 10, 1927. These nymphs were observed with the beak imbedded in the potato, apparently feeding. All of them clawed loose many bits of potato and attempted to arrange them near the opening of their cells. A small lump of dirt placed in one hole was used to cement the space around the window. It did not seem to be the light from the opening that worried the cicada, but the air that got in about the edge of it, and when this was sufficiently closed no more attention was paid to this sort of occupation. While this experiment would discourage the hope of using potatoes as hosts for cicada nymphs for any considerable period of time, it did give evidence that the above technique might prove a convenient and highly successful method of transporting nymphs for long distances. It seems probable that by using a little care in making the hole in the potato approximately the size of the normal cell and carefully sealing it shut to prevent desiccation and escape, nymphs might be so shipped with minimum expenditures of preparation, postage and fatality.

The second method has proved more successful. At first the nymphs sealed the cells with soil, but, failing to find food elsewhere, they eventually came back to the potato. Often when the potato was raised for observation the beak of the cicada would be so firmly imbedded that the nymph was raised out of the cell. They tunneled

about in the pan considerably, sometimes two nymphs opening holes very near each other. The nymphs in this type of container frequently opened their cells to the outside and left them open for days at a time. No explanation is offered as to why this was the case. An examination March 12, 1927, showed three nymphs in well developed cells in the bottom of the container living on the roots of the potatoes, which at this time had begun to grow. They seemed in fair condition, and might emerge in due time. It is possible that cicada nymphs can be carried through their entire cycle in this manner. However, success seems to be due not to the tuber but to the roots that form from it.

OTHER PLANTS. Experiments were conducted with a number of other plants. Wheat suggested itself as a winter food, but it proved to be too easily injured by changes of moisture and by disturbing the root mass in making examinations. Orchard grass, *Dactylis glomerata* L., and dandelion, *Taraxacum officinale* Weber, were next tried with excellent results. In about two weeks after transplanting they fill the cages with a wonderful system of tender roots, thus making it easy for the newly hatched or transplanted nymphs to find abundant food. In November, 1925, cages of this sort were carried in a car 400 miles to western Kansas and back again; nymphs were planted in them in the field, the grass lived, also the nymphs, some of them emerging this past summer (July, 1926). Blue grass, *Poa pratensis* L., *Sorghastrum nutans, Panicum virgatum,* orchard grass, dandelion and yucca were all used in large cages. Any of the above, with the exception of the first and last, appear to be satisfactory. Preference is shown, however, for the large-stemmed grasses because of the greater extent of the root masses. (Pl. XXXIII, Fig. 3.) Orchard grass forms many roots branching horizontally, which would increase the probability of newly hatched nymphs finding food, but the roots extend only a few inches deep. Dandelion grows deep but does not produce as dense a root mass, leaving the greater probability of tiny nymphs failing to find them. Yucca suggested itself because *Tibicen bifida* (Davis) eggs had been gathered in great numbers in Scott county, Kansas, placed in dead yucca stalks. It is a hardy plant, but the root system is too coarse and unbranched.

Because so many of our Kansas cicadas live in trees, experiments were started with trees as hosts. Willow, cottonwood, maple, and elm were potted. Trials with these have not proceeded far enough

to draw definite conclusions as to their worth. A fifth instar of *Tibicen auletes* (Germar) taken from oak and placed in a cage of willow on June 25, 1926, emerged in August. Some *T. dealbata* (Davis), fifth-instar nymphs, placed in the same sort of cages in August, 1926, are still alive and doing nicely February 9, 1927. These meager results, however, would indicate that small trees may be successfully used in live cages. The trees are less hardy, however, and more apt to succumb to inadequate quarters than grasses.

LARGE GLASS-SIDED CAGES. During the second year it was found that some of the earthenware pots had been so badly broken by freezing and thawing that it was necessary to replace them. In trying to overcome this difficulty large glass-sided cages were made after the pattern of the smaller ones. Eight by ten glasses were used and placed on a framework of wood two to four inches deep. The glass was countersunk and held in place by wooden cleats. These cages proved most convenient and desirable in every way, except that the wood decayed (Pl. XXXIII, Fig. 1). Not only does the decaying render the cage difficult to handle and necessitate ultimate replacement, but large nymphs will burrow through it and escape. A fifth instar, *Magicicada septendecim* (Linn.), placed in a large cage of willow on June 1, 1926, had escaped in this manner before February 3, 1927, yet the cage was solid enough to hold together (Pl. XXXIII, Fig. 2). A more durable cage is now being constructed by using heavy galvanized iron for the sides.

TRANSPLANTING NYMPHS. Where nymphs are transplanted one side of the cage is removed and a hole large enough for the individual is made near the root. Transplanted nymphs, if placed near the top of the cage with only loose soil covering them, tend to work to the surface instead of going down. If they are being placed in pots which have been growing for some weeks, the soil may be removed intact by inverting the pot and artificial cells made for them among the roots several inches beneath the surface. As the nymphs are found at all depths from two to twelve inches in nature, they may be placed at varying depths in the cages. Care should be exercised to make these holes large enough to allow room for the nymph to use its legs and to turn over to place loosened dirt in another part of the chamber. About 40 nymphs, so placed among choice roots, were found dead when examination was made, because they had been placed in cells too small to allow them to work.

When nymphs were transplanted in the winter the cages were

allowed to remain in a warm room until the nymphs had time to perfect their cells. This is essential, because they will not dig at low temperatures, yet they need the well-formed cell to protect them from drying and flooding, from injury from jar and attack from enemies. It is also considered that they feed in winter, so they should have their cells built around the food roots.

CARE OF CAGES. Cages containing nymphs are kept buried to the top in the open when not needed for observations. If exposed to air for long periods it is more difficult to keep the moisture content right for the host to thrive.

Observations should be made frequently enough to catch any changes which occur. During molting and emerging seasons daily examinations are desirable; or, if one hopes to observe the actual act of molting or transformation to adult, material must be kept under almost constant observation. If the glass becomes soiled, it may be removed, cleansed, and replaced. Often the glass will form a portion of the cell and activity may be observed with the cage intact. Cages containing nymphs which are nearly ready to emerge are kept under large frames covered with screen wire or mosquito netting. No protection is needed from rain or freezing after the nymphs have had time to form their cells.

REARING FROM EGG TO ADULT.

CARE OF EGGS. Unlike the nymphs, the eggs require very little care. So far but one species has been studied whose eggs dry up when the host plant withers. Although good eggs have been found in twigs which have been dry for long periods and also in stems badly molded from excessive moisture, natural conditions are maintained as nearly as possible by suspending the twigs bearing nests in trees out of doors soon after collection. Even eggs placed in dry tissue will shrivel if kept for a long time in very dry atmosphere.

HATCHING OUT OF DOORS. At first eggs were simply placed over pots containing the host plant and left to hatch naturally. It was thought the mortality was needlessly high with this method, due to a number of things. A hard storm, high wind, soil too wet or dry, might be disastrous to great numbers. Ants have been found on the stems containing the nests, devouring the nymphs as they emerged. The predacious enemies in the soil were also numerous. The defenseless nymphs must run the gamut of all these dangers.

HATCHING INDOORS. To reduce the mortality, the nests were taken into the laboratory as soon as red eyespots appeared. Flat-

bottomed trays with a smooth surface were found most convenient as containers. The stems were moistened daily, and when hatching began were kept covered. Nymphs left in dry air become desiccated in a few minutes, but, if kept in a moist chamber, will remain in good condition for several hours. Moisture was supplied either by a damp cloth covering or a moistened sponge placed inside the tray. Excessive moisture is undesirable because the nymphs are helpless if caught in the surface tension of a drop of water. It became the custom to dip the nests in water and place the tray in the morning sunlight. Within an hour the eggs would begin hatching, and by the end of two hours the largest part of that day's hatch would be out. Newly hatched nymphs will not injure each other when placed together as do the older instars. Dozens of nymphs may be allowed to crawl about together without injury. At frequent intervals during the hatch the nymphs were removed, counted, and placed in cages.

CAGES FOR FIRST-INSTAR NYMPHS. When the nymphs were being plated for the purpose of obtaining data on the digging and feeding habits and on the time of the first molt, the small glass-sided cages were used. On the other hand, when the completed life cycle was desired, large flower pots or large glass-sided cages were used. In either case it is most essential to use cages that are well filled with healthy root masses. The soil should be thoroughly moist, yet not wet. If the soil is too dry the nymphs cannot form their cells. If it is too wet they will leave, if possible, and many of those that remain will become glued to their surroundings in some helpless position.

A few newly hatched nymphs were placed in a plate cage containing moist cellucotton instead of soil around the grass roots. Observations were made under the binocular microscope. They crawled hurriedly back and forth over the roots, into one crevice after another, seeking for the necessary dirt for a home. This frantic search continued until they became caught in drops of moisture or were otherwise stopped. There seemed no doubt that the first instinct, that of forming a cell, must be gratified before food could or would be taken, and the idea of a soilless cage was abandoned.

Newly emerged nymphs, dropped on the surface of the soil, soon disappear into cracks or crevices and readily find their way beneath the surface. A more desirable way of transplanting, however, is to

remove one side of the glass cage and drop the nymphs upon the uncovered surface directly over the root mass.

CARE OF LIVE CAGES. If the small cages are left lying on the side for a few hours, many cells will be found against the under glass, giving the observer an ideal opportunity to watch cell-forming and feeding habits. Cages should not be wet after the introduction of newly hatched nymphs until these nymphs have had time to form their cells. Two problems confront the caretaker when the new nymphs have been plated. The host must be kept in good condition and the tiny nymphs should be protected from predacious enemies if possible. With the hardy plants which are used exclusively now, the first problem may be solved simply by burying the cages out of doors with their tops level with the surrounding soil and leaving them in this natural condition. Only in extreme drouth is any care needed. However, cages containing dozens of nymphs thus buried in the open have been entirely depleted in a short time by predacious enemies, probably largely by ants, while those kept in the laboratory were undisturbed. The problem of freeing the soil from animal life without using chemicals which will injure the cicadas when introduced, or by using treatment which will not injure the plants which must be hosts for them, is now being attacked.

COLLECTING LIVE SPECIMENS—ADULTS. To collect adult cicadas in the wild is a task requiring some skill and much time and determination, but to obtain observations on all their habits in the field would be a herculanean task. For museum purposes they may be killed with small shot shells, but to hope to get their story they must be taken alive. Some small species may be collected by sweeping. To take the larger and more wary kinds a long-handled net has been devised. The male may be found by his song, but careful scanning up and down the trunks and limbs of trees or other hosts is the only method of locating the females. No sure-catch methods have been devised. Sometimes they dart quickly out from the tree, sometimes to one side, sometimes to another. Again, if the female happens to be ovipositing, a quick sweep of the net may break her ovipositor, rewarding her captor with only a useless, mutilated specimen. However, a certain skill may be developed by practice.

LIVE CAGES FOR ADULTS. Live specimens of several species were placed in a wire cage on green limbs freshly cut from surrounding trees. Not a male sang, not a female oviposited, nor did a pair mate. Within two days all were dead, most of them having suc-

cumbed during the first afternoon. A wire cage containing a female *Tibicen dorsata* (Say) was then placed over a small walnut tree. Within a few minutes she was observed with her beak pressed against the bark obviously feeding. She lived several days in captivity feeding a large portion of the time. She also made several nice series of nests. It was assumed in succeeding work that all adult cicadas must feed if they were to live and function, and live specimens were always placed in cages over living plants or trees. A convenient form of cage is a mosquito net bag approximately a yard square left open at one end. This may be slipped over a twig or small tree or weed and tied shut. A small opening in the closed end makes a convenient place for inserting the cicadas, and may be pinned shut once they are inside. This type of live cage has given excellent satisfaction. It is inexpensive, collapsible, and can be quickly attached to any desirable host. Also, the soft material does not injure the excited captives when they strike it. Incisions can easily be made in this type of cage, if it is desirable, to make observations at closer range.

TRANSPORTING ADULTS TO THE LABORATORY. A pasteboard box with close-fitting lid is used to carry live adults from the field to the laboratory. Green pieces of weeds placed in the box give them something to cling to and reduce their nervousness materially. An attempt to transport live adults 200 miles in a mosquito net bag over a live transplanted tree in an open car was most disappointing. Many were dead at the end of the trip, and all died within the next thirty-six hours without having given any records. A few weeks later, however, a similar number were carried about the same distance in a heavy pasteboard box about 18x18x24 inches filed with green twigs. While some of those died in transit, some of all species represented remained alive. When put in live cages the males sang, both sexes fed, mating was observed, and many eggs were laid. One male sang lustily for three weeks.

MAKING OBSERVATIONS IN CAGES. If one moves quietly and slowly about the cages, the captive cicadas pay little or no attention, and all the normal habits may be observed at length. Photographs of captives have been made by cutting a hole in the netting and folding back the edges to allow better lighting and unobstructed view for the lens. It was found desirable in such attempts to work rapidly but quietly and gently, for the least disturbance would stop the operation and even if undisturbed the cicada might cease

when the nest was completed. Prolonged observations have also been made by placing a live cage on a table out of doors and clamping the binocular to the table. Numerous ovipositing females have been observed in this manner.

REMOVING ADULTS FROM CAGES. Cicadas in copula may be removed from the cage by picking them up in the hand and placing them wherever desired. They seem to have no fear, and may be placed in the open and moved about at will.

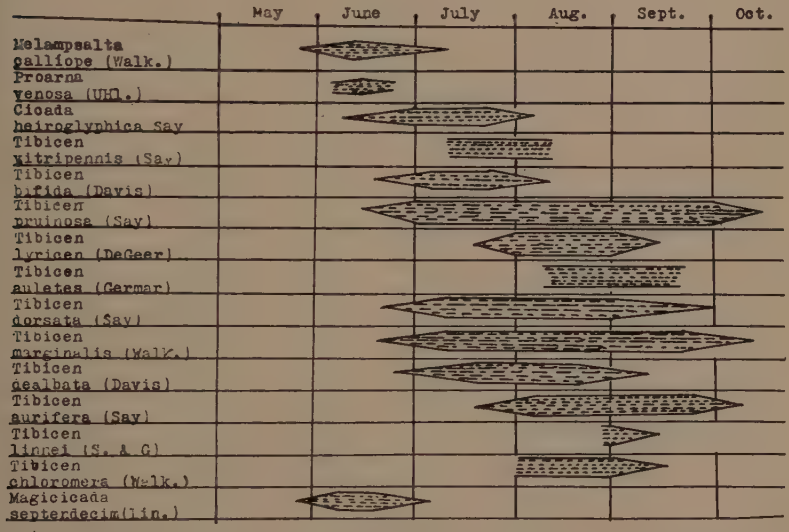
If it is desirable to remove females which are ovipositing from the cage, extreme care is necessary, and, even with the utmost care, only a small percentage of trials have resulted in success. When this was contemplated, dead sticks or live twigs, whichever was the normal host, were placed in the cage in a manner to be removed easily.

GENERAL NOTES.

BROODS. Queer, indeed, would be a Kansas summer without the songs of a half dozen species of cicadas. Although they are always with us, they rarely appear in sufficient numbers to be generally thought of as broods. Even then great numbers occur only in restricted localities. A few of these, however, are perhaps worthy of note. *Cicada hieroglyphica* Say emerges almost every year in blackjack oak, *Quercus marilandica*, in the southeast section of the state. A fairly large brood came out in June, 1926. In an isolated valley near Woodbine, Kan., a large brood of *Tibicen auletes* (Germar), emerged in 1923, and about one-half as large a brood in 1924, with practically none in 1925 and 1926. A noticeably large brood of *Tibicen lyricen* (DeGeer) emerged near Garnett, Kan., in 1923. It has not occurred there in so great numbers since. Our commonest eastern Kansas cicada, *Tibicen pruinosa* (Say), emerges in what appears to be almost constant numbers each season. The other species occur in varying numbers and places, some every year and others perhaps not so often, at least in the same localities. Thus while *Magicicada septendecim* (Linn.), the most famous member of the family, is represented by only an occasional herald one year, appears in countless number the next, a few lone stragglers the third, then the species disappears altogether for a number of years, apparently all other species which occur in Kansas appear in greater or less numbers every year, and no other species has been observed which approaches *Magicicada septendecim* (Linn.) in the density of one brood. There seems no reason, however, to question that each

species of cicada requires a definite number of years in which to complete its cycle, just as the seventeen-year one.

There is considerable variation in the time of emergence of different species of cicadas. The early species emerge in June and July, the late ones in August and September, while others appear in varying numbers throughout the season. Emergence time is constant from year to year with a species in a given locality, but does not hold for other species of the genus. Thus while *Tibicen bifida* (Davis) appears in June, *Tibicen aurifera* (Say) occurs in small numbers throughout the summer, being one of the last to cease its song. The following table illustrates roughly the time of emergence of the species:



LENGTH OF LIFE OF ADULT. No data have been obtained on the length of the life of the adult individual in the field. Specimens have been kept in captivity from a few hours to three weeks. It seems probable that some species will live nearer their normal life in captivity than others. A male specimen of *Magicicada septendecim* var. *cassini* (Fisher) taken before it had completely hardened, lived in a live cage on cherry for two weeks. A male of *Tibicen dorsata* (Say), which had been taken when active in the field, transported 200 miles, and placed in a live cage on apple, lived three weeks.

EMERGENCE FROM THE SOIL. Emergence from the soil in every case observed has been accomplished through a more or less regular

hole. Only in rare cases has there been a semblance of a hut or a cone, as is sometimes the case for the seventeen-year cicada. The normal time of constructing the emergence chamber has not been computed. A *Melampsalta calliope* (Walk.) fifth-instar nymph, dug its cell to within one-fourth inch of the surface twenty-six days before it emerged. No period of resting was detected, the nymph being observed at the bottom of its cell feeding shortly before transformation. One *M. calliope* (Walk.) fifth-instar nymph, transplanted from the field to a cage, emerged in ten days from a well-developed underground chamber which it had constructed. (Pl. XXXIII, Fig. 6.)

TRANSFORMATION TO ADULT. Observations have been made on the actual act of transformation from the nymph in but one species. However, dozens of cast skins of numerous species have been collected. Small species like *M. calliope* (Walk.) tend to cast their skins much nearer the emergence holes than larger ones. All seem to prefer night as the time for transformation. No variation has been noted in the way the skin splits or the method of holding to the support. The nymph comes to rest in a vertical position with the head up, or in a horizontal position on the underside of the limb, attaching itself firmly by the middle pair of legs.

FOOD HABITS OF THE ADULT. All data tend to show that adult cicadas of both sexes feed regularly and often. Both *M. calliope* (Walk.) and *Proarna venosa* (Uhl.) have been observed to feed between the making of nests during oviposition. A female of the latter species was seen to insert her beak into a stem of dry grass in which she regularly oviposits. Whether she obtained any food from it or not it was not possible to tell. In every instance the first thing the adults were observed to do when placed in a live cage was to feed and, given food, most of the species obtained mated, the males sang, and the females oviposited in captivity. In all cases where food was withheld the adults died within forty-eight hours at most.

THE SONG. All of our Kansas cicadas have individual songs, with the exception of *Tibicen dealbata* (Davis) and *Tibicen marginalis* (Walk.). Their songs seem to be identical. That the song of the cicada is a secondary sexual character has been generally accepted. No record has been found of observations of females following the songs of males, but two interesting types of experiences are given where females have been attracted by rhythm similar to the song

of the male of the species. Mr. Annandale, writing on "Insects of the Skeat Expedition to the Siamese Malay States," in 1899, says:

"At certain seasons this cicada, *Dundubia intenerata*, forms a regular article of diet among the Siamese inhabitants of Patalung; and as their method of capturing it is based upon a knowledge of its habits, I cannot do better than give an account of this method, as I saw in operation at Ban Nah, a village on the border of the hill country of Patalung. Immediately after the sun had set several of the natives gathered in an open space, round a fire of brushwood or a number of torches fastened to stakes stuck into the ground, and commenced to clap their hands in unison, observing a regular time and rhythm. Very soon, if they were fortunate, the Cicadidæ flew out from the undergrowth of the surrounding orchards and jungle and alighted on the persons of their captors, who had no difficulty in picking off the insects with their fingers and securing them, still alive, in the fold of their draperies. The clapping only continued for about half an hour every evening; and when, with considerable difficulty, I persuaded the men to recommence it again later in the night, not a single cicada came near them, though the stridulating had now become loud all over the village, like the noise of machine hair-brushes in a barber's shop.

"The insects were silent on the wing, and I only heard one stridulate when caught. The voiceless females, as might be expected, were in great preponderance over the males among the specimens taken; probably the one individual which was not dumb when captured was the only male taken that night. In order to be sure that the fire was not the chief attraction for the Cicadidæ, I stood among a party of natives who were clapping, together with another member of the expedition, who clapped also, while I kept my hands still. In the course of a few minutes the natives captured many specimens, and ten alighted on my friend's coat; but only one settled on mine. Afterwards I heard from a Patani Malay that the children of Patani have a game in which they attract cicadas by clapping their hands, and without the aid of light at all; though they sing, as they clap, a nursery rhyme, calling upon the insects to come down from the trees."

A personal experience lends similar evidence. Numerous *Tibicen dorsata* (Say) females were collected on the cab and other parts of a Fordson tractor which was being driven through a weed-grown field. Not a male was taken. Persons have been known to mistake the song of this cicada when quite near for the hum of a distant tractor, and it seems reasonable to suppose that the sense organs of the female which record vibrations recognize a similarity in the two sounds. In both instances the females of only one species were attracted, although other species were present in the localities.

Perhaps the most direct proof of the relation between sex and song is the fact that in captivity the other males in a cage almost invariably sing when a pair is mating. They have been observed crawling around and over the mating pair singing with all their

might. Not only one male, but several at a time, will react in this manner.

That the males also detect sound is indicated by the fact that singing in one cage provokes the singing of males in adjacent cages, even when they are of different species. It was also noticed that the singing of males in cages often excited answering songs by males in neighboring trees and, *vice versa* songs within hearing of the cages were answered by captive males. Likewise one male may break the silence on a summer afternoon to be joined almost immediately by males on surrounding hosts.

MATING. Matings occurred frequently among the cicadas in the live cages. Often several pairs would be in copula before the specimens arrived at the laboratory from the field. The act of copulation takes from a few minutes to an hour and a half. The same female often mates with different males. In one instance a male *Tibicen pruinosa* (Say) mated with a female *Tibicen chloromera* (Walk.). This occurred while transporting a number of species together in one container. Mr. W. J. Rainbow writing in Rec. Austral. Mus. v, p. 116, gives an account of the mating of two cicadas belonging to different genera. He also includes a photograph of the pair.

During the act of copula the pair seem to pay no attention to their surroundings, and may be removed from the cages for photographs or other observations.

OVIPOSITION. The mechanics of oviposition is practically the same for all species. As the abdomen is raised from the support the ovipositor springs from the protecting valves. The point is placed against the host at a right angle to it, and by a rotating motion of the whole organ and an in and out motion of the two valves it is gradually driven into the tissue. As it pierces the material, the angle is lessened so that the hole turns down, finally parallel with the surface instead of directly into it. When sufficient room is made for the nest, the process of placing the eggs is begun. These are laid usually in two rows the full length of the nest. The bottom end of the egg is placed at the back side of the cavity and the outer end against the outer side. (Pl. XXXI, Fig. 3.) There may be one or more nests made from the same external opening depending on the species.

NESTS. The nests may or may not be arranged in a definite order in the host plant. *Tibicen aurifera* (Say), *T. marginalis* (Walk.), *T. dealbata* (Davis), *T. vitripennis* (Say), *T. dorsata* (Say), *Melampsalta calliope* (Walk.), *Proarna venosa* (Uhl.), and sometimes

Tibicen bifida (Davis), exhibit an orderly arrangement of their nests, while the others noted scatter them more or less at random. Except in the use of grass stems, regular arrangement tends to be found where green tissue is used, irregular where dead.

Some species make use of secreted gluelike material both at the beginning and closing of a nest. *Proarna venosa* (Uhl.) exudes a liquid on the dry grass stem when she places her ovipositor against it. Again as she withdraws the ovipositor from the nest, she fills the opening entirely with a white frothy material. *Tibicen lyricen* (DeGeer) not only fills the opening full of secretion, but presses the torn tissues back into place with the fleshy sheaths of the ovipositor, leaving the external evidence of the nest difficult to see. Unlike the above, *Melampsalta calliope* (Walk.) does not place any secretion in her nests. This omission may account for the fact that her eggs shrivel as soon as the host begins to wilt.

EGGS. The number of eggs in a nest varies from three in *Cicada hieroglyphica* Say, to as many as twenty in some *Tibicen aurifera* (Say) nests. The arrangement of the eggs of most of the species follows that shown in (Pl. XXXI, Fig. 3) *Melampsalta calliope* (Walk.), however, sometimes uses a different arrangement. (See Pl. XXXVIII, Fig. 4.) In the stems of sweet clover, at least, she places her eggs in a fan-shaped figure, starting as low as convenient in the hollow stem and placing one egg on top of another up to or a little above the entrance of the nest. Cicadas which oviposit in different types of tissue may be influenced in the size of the nest by the nature of the nest. Mr. Wilman Newell writes in the U. S. Dept. Agri. Bureau of Ento. Bull. 60, pp. 52 to 58, of *Tibicen vitripennis* (Say) placing 75 eggs in a hollow stem from one opening. *Melampsalta calliope* (Walk.) regularly places from 12 to 16 eggs in a nest in asparagus or sweet clover, but only three in the stems of the compass plant, *Silphum laciniatum* L.

HOSTS. No species has yet been observed which uses only one host for oviposition. Attempts have not been made to list those used by any of the species because observations tend to show that they will use almost any material. Mr. Newell, writing in the report mentioned above, records *Tibicen vitripennis* (Say) ovipositing in the walls and roofs of sheds, in fence posts, in all kinds of weeds, in cotton, in corn, and even in the handles of hoes left in the field. Some one has observed a cicada attempting to oviposit in an iron bar. *Tibicen pruinosa* (Say) has been observed in the laboratory oviposit-

ing in the wooden side of a cage. A species may show a marked preference, however, for some particular material. It may be anything from soft green weed stems to the very hardest of dead oak twigs. Although some species seem to prefer hard wood, the majority choose softer materials. The old corky bark of elm and willow is a favorite. Partially decayed twigs are also used. Plants with a pithy or hollow center, as sweet clover, cotton, corn, etc., are chosen by some species. While most species prefer either live or dead tissue, practically all will use the other if their preference is not at hand. *Tibicen pruinosa* (Say) and *Cicada hieroglyphica* Say have not been observed to oviposit in living tissue. Where twigs are chosen for nidification they are usually of a size convenient for the cicada to grasp with her legs.

EFFECT OF OVIPOSITION ON THE HOST. Where oviposition occurs in green tissue, the death of the stem sometimes follows. Newell reports a total loss of some cotton fields in Louisiana in this manner. In July, 1925, a field of cotton was inspected in Oklahoma by the author, where perhaps one-tenth of one per cent of the plants had been killed or severely injured by the oviposition of *Tibicen vitripennis* (Say). *Tibicen dealbata* (Davis) in western Kansas often oviposits so thickly in cottonwood twigs that the twigs die, either directly from the maceration by the ovipositor, or are so weakened that the wind breaks them off. It is no exaggeration to say that this species often cuts in shreds limbs one-fourth inch in diameter for a space several inches in length. Unlike the seventeen-year cicada, none of the species so far studied, except, perhaps, *Tibicen vitripennis* (Say), become numerous enough to be of any considerable economic importance in this way.

EGGS. The eggs of the different species of cicadas vary in appearance only as to size. Those of *Tibicen auletes* (Germar) measure about 2.75 mm. in length and .5 mm. in width, while those of *Proarna venosa* (Uhl.) measure about 1.6 mm. in length and 0.4 mm. in width. The chorion is smooth, shining, and transparent, revealing the internal structure distinctly as the embryo develops. The eggs are white in color and somewhat spindle-shaped, a little more sharply pointed at one end than at the other.

The length of the egg stage varies from one to three months in those species which hatch the same summer, and from nine to twelve months in those which hatch the following year. Among the species studied which oviposit in live tissue, *Melampsalta calliope* (Walk.) is the only one whose eggs wither with the wilting of the host. In

all the others, even though the host dried, the eggs remained in perfect condition, if they were kept in outdoor conditions of temperature and moisture. Marlatt, in Bull. 71, U. S. Dept. of Agri., pp. 111, in discussing the eggs of the seventeen-year cicada writes as follows: "As is the case with most insects that oviposit in the living parts of plants, the eggs of the cicada receive a certain nourishment from the plant and actually increase in size before hatching, by absorption of the juices from the adjacent plant cells." Of the species studied *Melampsalta calliope* (Walk.) is the only one which could possibly obtain nourishment from the host, as the others, even if placed in green tissue, are capable in themselves of developing and hatching normally though the host dies. The eggs of all species show red eyespots, and later tarsal claws on all the legs, some time before hatching. In those of *Melampsalta calliope* (Walk.), *Tibicen bifida* (Davis) and *Tibicen vitripennis* (Say) the whole egg turns pink and the first instar nymph is pink after hatching. Fabre refers to those he studied as resembling a grain of wheat in color. All others studied remain white.

HATCHING. As has been mentioned earlier hatching appears to be influenced by moisture and temperature. A few stems containing eggs were left dry in the laboratory, while the remainder were moistened daily. When the hatch was practically complete in the moist stems and had not begun in the dry ones, these latter were dipped in water for a few seconds and then placed in warm air. Within an hour the eggs were hatching rapidly. A cool day during the hatch has also been noticed to stop the emergence temporarily.

In hatching the embryo bursts the egg capsule anteriorly and wriggles its way to the nest opening. The complete hatch of a dozen or more eggs is accomplished with little or no disarrangement of the empty shells. Usually the egg nearest the opening hatches first, and the others follow in inverse order to that in which they were laid. This is not invariably true, however. When the nymph emerges from the nest, it is still inclosed in the postnatal skin—a very thin, transparent membrane. Although the appendages are each incased in a separate sheath, all are folded ventrally against the body and remain stiff-jointed and useless until this skin is cast. The emerging nymph reminds one of a fish, both in general shape and in the wriggling motion by which it works its way along. The postnatal skin splits dorsoanteriorly. This is accomplished by repeated contracting and expanding of the body, which resembles an undulating motion. The anterior end becomes greatly distended, then reduced. So

transparent is the skin that the only evidence of its splitting is the appearance through the slit of the hairs of the nymph. Gradually the antennæ are pulled free from the skin, then the front pair of legs. They immediately begin moving these large, digging front claws, opening and closing them. Within a few seconds all the legs have been freed and the abdomen slips easily from the wrinkled skin. When the eggs are hatching normally, it requires about five minutes from the time the anterior end of the embryo appears in the nest opening until the first instar nymph crawls away. The postnatal skin remains attached to the nest. The individual which is casting its skin may be projected entirely above the nest from the anterior end of another egg. Even the second nymph has been observed forced clear of the nest by the third. Only one casts its postnatal skin at a time, however, and when the hatch is completed the cast skins are grouped about the nest entrance. These appear to the naked eye to be tiny funnels, but a careful examination reveals a complete exuvium.

Occasionally the egg may be turned wrong end to in the nest and the emerging nymph fails to find the nest opening. Where nests are made in hollow stems, *Tibicen aurifera* (Say) nymphs have been found two or three inches down the stem searching in vain for a way out. Eggs removed from the nest usually do not hatch. This is probably due to the lack of support to hold the shell while the embryo breaks it. However, nymphs falling from the nest opening before casting the postnatal skin have been observed to wriggle continuously until they finally free themselves. This requires much longer than when it remains attached to the host, and a little excess of moisture in the receptacle or air which is a little too dry is fatal to the nymph.

Much variation has been experienced in the rate of hatching. *Tibicen aurifera* (Say) has been observed hatching so rapidly that the tiny white forms resembled scattered aphids on the stems. As many as 600 newly hatched nymphs of *Tibicen dealbata* (Davis) have been removed from a handful of twigs in one day. On the other hand, just an occasional postnatal skin or empty eggshell in the nests marks the hatching of one egg at a time in other species. Usually with the eggs in the laboratory the largest hatches come near the beginning, the number soon dwindling to only a few. Examinations of the nests indicate that all of the eggs of a nest rarely hatch in one day, but that in nests with large numbers of eggs most of them

hatch within a few hours. The one or two remaining eggs may wait several days before hatching.

Among the species observed the hatching period of the eggs is much shorter in those which overwinter in the egg stage than in those which hatch the same season laid. Thus, while the nymphs of *Tibicen aurifera* (Say) emerged within a period of eleven days, *Tibicen bifida* (Davis) has been observed to hatch over a period of fifty-one days. It seems probable that this great variation in the time of hatching may be due to the difference in the time of oviposition. The development in the eggs which overwinter appears to be complete when spring comes, and all eggs of all species are ready to hatch as soon as the temperature becomes high enough for the last phases of development, regardless of the time laid. Thus *Tibicen dealbata* (Davis) eggs laid in July began hatching only three days earlier than eggs of *Tibicen aurifera* (Say), which were deposited in September. They all hatch within a few days of each other. Development may be accelerated by bringing the eggs into the warm laboratory early in the spring. Unless the nests have been parasitized or have been exposed to extremely arid conditions the percentage of eggs which hatch is high. In fact, examination of numerous nests often shows 100 per cent emergence.

IMMATURE STAGES. The newly hatched nymph with its front legs so peculiarly adapted for digging, its large antennæ, and hairy appearance in general, presents a really grotesque figure as it scrambles away from the nest. These are quite active as compared with any of the other instars, running about over the twigs which contained the nests or over the bottom of the tray, as the case may be. As other writers have said, the nymphs hatching in nature rush over the sides of the limbs and cast themselves into space as though the wings of their progenitors would bear them safely to the earth. It is here, no doubt, that the wind plays an important role in the distribution of the nymphs beneath the trees. As has already been stated the north side of trees seems to be the most likely place to dig for immature stages. The fact that our prevailing winds are from south to north agrees with these findings.

In the laboratory, at least, the nymphs seem to be attracted by moisture, although a cage with the soil too wet tends to repel them. However, the tiny individuals fresh from the nests are extremely sensitive to desiccation. But a few minutes subjected to dry air is sufficient to kill them. In order to make observations of nymphs

under binoculars they must be placed on a moist pad. In a dry container one can watch the tiny creatures shrivel and die, the process taking scarcely longer than it does to write these words.

Newly hatched nymphs are phototropic, but after they have entered the soil light does not seem to affect the nymphs in any way, either in this instar or any other, when once an individual has its cell finished. Even though a part of the cell is glass and the light comes in freely, the nymph will often continue feeding for weeks without changing its home or showing in any other way what might be construed as a reaction toward light. Even when a strong electric light is thrown on them for observation, no reaction whatever can be noticed.

Unlike all the other instars, this is not affected by a sudden jar or other disturbance. Nymphs may be transferred from a tray to a cage by shaking the container over it, and, though they may fall a foot or more, all of them, upon touching the soil, will be moving. In the other instars there is a tendency to "play possum" when disturbed. The baby nymphs pay not the slightest attention to one another. If gathered together in a small space they will scramble over and over each other without injury, while the individuals of the other instars, if placed together, will soon kill one another.

NEWLY EMERGED NYMPHS. Newly emerged nymphs, upon reaching the ground, crawl about until they find a crevice which they can enter. They have never been observed attempting to dig from the surface in the laboratory although Fabre records nymphs digging beneath the surface, leaving openings which resembled pin holes. Excellent opportunity to watch their first operations has been afforded by the use of the small glass-plate cages. Many nymphs of different species have been observed during the first few hours of nymphal life and the actions are so characteristic, so alike in all essentials, that it seems safe to give a generalized description which may be applied to all. Occasionally the first crevice entered does not please the newcomer, and it returns to the surface and crawls about until it finds another. Within a few seconds, however, it has disappeared. The only exception to this rule is found when nymphs have been exposed to excessive moisture. If they have fallen into the water when hatched, or, if the soil is saturated with water, they remain above ground until a normal moisture content is reached.

UNDERGROUND. Underground the nymph is an explorer whose

only compass is an instinct to go down. It wends its way through numerous openings, over roots, through narrow passages, feeling ever with the long antennæ. Occasionally it stops to remove a load or two of dirt from a narrow place, always being careful to place what it has removed in some other part of the passage. In a short time it finds a plausible site for a home and begins work in earnest. Using its highly modified front legs as pick and shovel, it is well fitted for the task. Tiny particles of dirt are picked from the side of the tunnel and either pressed against the postclypeus or in a ball between the front legs until a load has been amassed. This load is a ball with a diameter about the same as the head of the nymph. It may carry this dirt stuck fast to the cephaloventral side of its body with or without the support of one front leg, or between its two front legs. It is usually carried to a distant part of the proposed cell where it is forced against the wall and smoothed out with repeated clawing motions. At first it crawls on all three pairs of legs, with them in a normal position, but, once in the semblance of a cell, the second pair of legs are used over the back. It works usually in a tunnel small enough that all sides of it may be reached with its legs, yet large enough for it to turn over. A cicada nymph never turns around, it turns over. Hence, when it has its load of dirt, it backs back a step or more, if necessary, to reach a larger place, and, describing a partial somersault, crawls away in the other direction. After depositing the dirt it repeats the process to return to the other end of the cell. The cicada's idea of a home is a cell, cylindrical, smooth-sided, tightly finished. Within a short time it has one completed. Then, and not till then, does it appear to think of food.

A nymph will run over roots and pay no attention to them until it has constructed its cell; but it will complete a perfect cell in mud in a pan which has no roots in it. If a root happens to be near the cell, it is soon happily feeding. Numbers of nymphs have been observed feeding in the morning after having been placed in a cage late the evening before. However, if food is not available, it begins a search for it. This is the most laborious process imaginable. It keeps the cell complete always, moving slowly downward by removing the dirt from the bottom end of the cell and placing it carefully at the other end. This is continued until food is found or death overtakes the individual.

This instinct of observing such extreme care to keep the cell in

perfect condition may not seem strange when one considers the dependence of the nymph on the prevention equally of desiccation and flooding. Not only will a nymph drown in a short time in water, but a newly emerged one is so light and so frail that it is unable to free itself from even a little excess moisture. After it is established, hard rains or even temporary flooding of the ground above may do no injury, but a light shower before the cell is constructed is disastrous. Again, when one considers that it is utterly defenseless if attacked by enemies, one must admit there is really a need for the care. The pincerlike claws are effective weapons when they strike their mark, but the blindness, slow movement, and lack of biting mouth parts seem to have been sufficient handicaps to the cicada in battle, so that its first reaction is nonresistance rather than pugnacity. Safety seems to lie in not being found. Judging from the pitifully few nymphs which develop after the hatching of hundreds of eggs, one feels that the precautions are none too great. This exceedingly high mortality is probably due largely to predacious enemies. Ants, no longer than the nymphs themselves, have been observed carrying away the helpless cicada, and cages in which nymphs have been placed have been found worked into fine particles by ants and other predacious animals. In such cases the most diligent search reveals not a single living nymph.

When searching for food the cicada feels constantly with its antennæ, and, when a root is encountered, claws at it with the front feet. The beak is inserted with some difficulty, the nymph apparently pushing against the opposite sides of the cell with the two hind pairs of legs. During feeding, the front claws remain idle, not touching the root. The body is usually nearly parallel to the root, though cases have been observed where the head was bent backward. When the nymph emerges from the egg the beak is straight and is carried close against the ventral side of the body. The above-mentioned cases of the head being held at an angle may possibly have been where the nymph was feeding for the first time and had not yet bent the beak, for in all his later life the nymph carries his beak bent between the front legs almost at a right angle to the body.

FIRST INSTAR. The length of the first instar apparently varies with the species. According to Marlatt, the seventeen-year cicada molts into the second instar in the second year, making the first stage perhaps eighteen months. *Tibicen vitripennis* (Say), in the lab-

oratory, molted the first time in six weeks. It seems probable that the length of the first instar may foreshadow to some extent the total life history of the species, although the data are, as yet, too meager to warrant definite conclusions.

The baby nymphs of most species are white in color, although some are pink. As to why some should be pink, no answer is apparent. The three species observed which have pink nymphs all hatch the same summer as the eggs are laid, but two other species, with similar habits, have white nymphs. It cannot be due to live or dead tissue in which the eggs are laid, because one species with pink nymphs oviposits in dead tissue while the other two use green. It is also interesting to note that the live tissue of one of the latter withers upon oviposition, while the other does not. This pink color appears to persist throughout the first instar, but is lost in the second.

The general shape of the body of the first-instar nymphs is more nearly cylindrical than in the next three instars. The head and pronotum are large and closely joined. The antennæ are over one-third the length of the entire body and about as large around as either of the back pairs of legs. The segments of the antennæ vary in number in different species and sometimes apparently within the species. The beak is nearly as large as the front femur in diameter and almost a third as long as the entire nymph. The eyes are represented by granules of highly colored pigment showing through the epithelium.

The legs are long and strongly built, with the front pair remarkably modified for digging. The tarsi are two-jointed, with two long tarsal claws, usually of unequal length. The apex of the middle and hind tibiæ is set with a number of strong, nonsetæ-bearing spines. The apex of the front tibiæ is modified into a beaklike projection with or without teeth on its cutting margin. The front femur on the ventral side is armed with a short, sharp, median spine, and a much larger, often more or less bifid, basal, beaklike tooth. It is these adaptations of the front femur and tibia which so admirably fit these insects for their underground life. The whole insect is sparsely covered with hairs and spines of varying lengths and sizes. Just before molting into the second instar the abdomen becomes distended, thus changing the general appearance of the nymph. In molting the skin splits in exactly the same way as in the fifth instar when the adult emerges.

SECOND INSTAR. The second-instar nymphs are quite noticeably

less active than the first. They are practically helpless when out of their cells. In color they are creamy white shaded somewhat with brown on the anterior half and the cutting parts of the front legs. The eyes, mere swellings on the side of the head, are always of the same color as the body, with the posterior half sparsely set with stiff hairs. The size of this instar varies considerably among the species, and some even within the species. The nymph now loses the cylindrical form which it presented in the first instar. The abdomen is much larger, tapering caudad and constricted anteriorly to meet the smaller thoracic segments. It also curls ventrally, more in some species than in others. This irregular form continues until the fifth instar, when the nymph again becomes nearly straight sided, due to the broadening of the thoracic segments.

The tarsal claws in many species lose all semblance of claws, becoming chitinous stubs, the anterior one usually very much shorter than the other. The large spines at the apex of the middle and hind tibiæ have large setæ projecting from their inner margin near the tip. The tarsus of the front leg has almost entirely disappeared. It is represented by a short, triangular-shaped segment so closely appressed to the anterior side of the tibia as to be practically indistinguishable. The whole tibia becomes more beaklike, and otherwise adapted for cutting and digging. The femur is further modified by the addition of a flat chitinous disc placed anterior to the median tooth. This has been called "the comb" by Marlatt. It is a flat, wedge-shaped piece with a varying number of teeth on its outer margin and is used in helping to shear the dirt from the sides of the cell. (Pl. XXXVIII, Fig. 8 [*d*].)

Unlike the first instar these nymphs show a decided reaction to disturbance. When they are rolled out on a heap of soil in the process of collecting them, it is some time before they will begin to move their legs in an effort to right themselves. This tendency to "play possum" is no doubt a protective measure. Frequently when a cell is broken into the inmate draws back from the opening and assumes a statuelike attitude, or perhaps first retreats to the depth of his cell and becomes quiet. In contrast to this is the pugnacious behavior encountered often when one opens a cell. Whether this difference in behavior is due to a difference in the nature of the disturbance as observed by the nymph or to a difference in temperament of the individual, it is impossible to say. Whatever the explanation, it has been observed that in a great many cases where a cell is opened without the nymph being ejected it rears up to the hole with both

front claws raised for an attack. This attitude is not all bluff, as evidenced by the fact that it will grasp a stick or tweezers viciously if it comes in reach. So tenacious is it that it may often be lifted clear of its cell in this manner. No difference has been noted in the pugnacity of the different species studied, but nymphs which have been starved will generally show fight if disturbed.

The individuals of this stadium are very difficult to find in the field because of their small size and the fact that their cells are so small they do not break open in the tearing apart of the soil.

THIRD INSTAR. The third instar closely resembles the second. There is a substantial increase in size; the wing pads are noticeable; the comb on the front femur becomes larger, with usually an increase in the number of teeth, and the antennal segments may increase in number. The length of the stadium varies with the species.

FOURTH INSTAR. The fourth instar is almost an exact replica of the third, save an increase in size. Sometimes faint fuscous markings appear on the borders of the sclerites. There may be an increase in antennal segments; the wing pads are distinct, and there is an increase in size of the comb on the front femur, with an addition of teeth. The length of the stadium varies with the species.

FIFTH INSTAR. When the fifth-instar nymph draws itself out of the exuvium which has encased it, the head and thorax broaden markedly, becoming wider than the abdomen, which is now somewhat diminished. Throughout this stadium the abdomen never becomes as distended as in the three earlier stages. The body of the nymph thus retains more of a rectangular shape, with the sides of head, thorax and abdomen nearly parallel.

The nymphs of some species are also strikingly colored with fuscous. Wide borders appear on the dorsal abdominal sclerites, the pronotum, and the wing pads. The segments of the antennæ and legs, also, often have conspicuous dark markings. In some species the entire nymph becomes a light brown marked by a darker color, in others the body remains practically white but strikingly marked with dark, while in still others very little color appears.

The changes in the appendages are quite radical. The number of antennal segments may increase and some of the segments may change shape. The tarsi all become two-segmented. Those of the front legs are normal in size, but are bent backward on the inside of the tibiæ, thus being out of the way of the insect's digging activities. The tarsi of all legs have two well-developed tarsal claws, one usually slightly shorter than the other. The comb of the front femur

becomes larger, and has additional teeth on its outer margin. The setæ-bearing spines of the middle and hind tibiæ usually increase in number. The genus *Proarna* is the only exception. This characteristic would seem to be of some generic value. The genus *Tibicen* changes from three in the second, third and fourth to five in the fifth, *Melampsalta* from two or three, and *Proarna* does not change at all.

The eyes in this instar are much larger and look more like eyes, although the posterior half is still covered with sparsely set hairs. The wing pads are long and show signs of tracheæ through the walls. Some little time before emergence the outline of the tarsal claws, spines, etc., of the adult may be seen through the nymphal skin. The eyes also change color in all the species noted. This fact is of great help in picking specimens which one knows will emerge in the next few weeks.

The fifth instar nymphs are decidedly more active when removed from their cells than any other since the first. The others can scarcely crawl on a flat surface, but tumble about awkwardly. This change is probably due to the better proportioned body. It is, of course, necessary, since the nymph must emerge from the soil and find a convenient perch for transformation.

ENEMIES. Perhaps the most conspicuous of the cicada enemies are the birds. Particularly noticeable is their ravage early in the season. Often within an evening the song of half a dozen males will end in the characteristic muffled squawk of the captive cicada, and an interested observer may see the bird flying away with its prey. Marlatt records the complete annihilation by birds of a brood of seventeen-year cicadas which had been artificially transplanted to a new locality and had emerged in great numbers.

Perhaps equally destructive, if a little less easily seen, are the large digger wasps, *Sphecius speciosus* Dru., or cicada killers. A comprehensive and detailed account of the habits and life history of this wasp has been given in Marlatt's paper. Cicadas appear to be aware of these enemies but rarely. Usually the wasp seizes it from behind, and together they fall to the ground where the cicada is stung until it is quiet. The cicada is utterly helpless when overtaken, but individuals have been observed to fly away when a wasp approached, and thus escape capture.

While birds and cicada killers are frequently observed taking the large, tree-loving species, the smaller cicadas have still other enemies.

Large robber-flies (Asilidæ) have been observed carrying away *Cicada hieroglyphica* Say, *Tibicen aurifera* (Say), *Melampsalta calliope* (Walk.) and *Proarna venosa* (Uhl.). These have also been found in the jaws of large spiders or securely fastened in their webs.

The adult cicada has still another type of enemy. Two different species of Sarcophagidæ (flesh flies) have been bred from the bodies of cicadas, and there are doubtless others which use them as hosts when opportunity offers. It is not an uncommon sight when collecting cicadas, especially of the prairie-loving forms, to see one or two flies follow a cicada when it takes wing. This is easily seen if the cicada happens to fly in just the right direction in regard to the sky line. The flies follow but a few inches away, and sometimes seem almost to alight on the body of the cicada.

In the egg stage clever little parasitic Hymenoptera cause great havoc in certain species. In some cases fully fifty per cent of *Tibicen aurifera* (Say) nests collected have been found to be parasitized, and a single grub normally consumes an entire nest of eggs. Similar parasites have also been reared from nests of *Melampsalta calliope* (Walk.) and *Tibicen marginalis* (Walk.), although so high a per cent of parasitism has not been observed in nests of these species. Grubs have been found in the nests of *Tibicen dealbata* (Davis) also, but the adults have not yet been obtained. Other writers have described and illustrated numerous species of mites which are also parasitic on the eggs of cicadas. No attempt has been made in the present work to study this group, but numbers have been observed in and about the nests of various species, and eggs have been noted which have the appearance of having been sucked dry by them.

From the time the tiny nymph crawls from the postnatal skin until it bursts its fifth instar skin and emerges as an adult, it is prized as food by various predacious animals. Ants have been observed on the twig bearing nests waiting to devour the nymphs as they hatch. In the soil, dismembered bits of small cicadas have been found in their jaws and scattered remains have been observed along their runs. No actual evidence has been obtained, but circumstances and the habits of the groups would suggest that chilopods and other forms of similar habits, doubtless play no small part in the control of cicadas.

Marlatt writes interestingly of the habits of hogs rooting up the ground where seventeen-year cicadas are about to emerge and feast-

ing on the nymphs, and of dogs and chickens and other domestic animals eating large numbers of the emerging ones. During excavations for seventeen-year cicadas, attention has been attracted frequently in this work to mole runs along the under side of roots near the surface of the ground. Where one is encountered it invariably runs the length of the root and never has a nymph been found under these roots, although they may be found in numbers only a few inches away.

MORPHOLOGY.

No attempt has been made to treat the morphology of the cicadas in an exhaustive manner. Drawings of the external parts of the adult, which are self-explanatory, have been made of *Melampsalta calliope* (Walk.). (Pls. XXXV and XXXVI.) A series of drawings of the external development of the genitalia of the sexes in so far as it could be followed is also included. (Pl. XXXVII.) Attention is called to Pl. XXXVII, Fig. 8, in which the œdagus hooks show through the body wall in the tenth sternite. This can be seen only in individuals with red eyes. No trace of the internal genitalia could be found in the fifth-stage individuals with normal eyes.

Melampsalta calliope (Walk.).

Because more data have been obtained on its habits and life history than on those of any other species, *Melampsalta calliope* (Walk.) is here considered first. Both adults and nymphs have been collected in greater numbers, and rearing experiments have been more complete in this than in other species.

This is one of the smallest of Kansas cicadas, measuring 12 to 15 mm. in length. In color it ranges from green to brown with an occasional pink specimen. The color seems to vary somewhat with the locality, those taken in Scott county being uniformly green, while those of other localities are usually light brown.

DISTRIBUTION IN THE STATE. This species occurs in every county in the state. Wherever prairie meadows are found, there one finds *Melampsalta*. There are, however, three localities which deserve special mention. The first of these is on the ranch of Mr. Herbert Steele, located in the Beaver Creek valley 14 miles north of Scott City, Kan. The particular location is a small, flat-bottomed draw perhaps 75 yards long and 50 yards wide, a short distance east of Mr. Steele's house and extending back from the creek itself. (Pl. XXIX, Fig. 1.) Although this depression is scarcely five feet below the surrounding land, the vegetation is very much heavier. It was here, in June, 1925, the adults were found ovipositing in goodly numbers. Upon examination of the soil, it was found to be fairly teeming with nymphs of all stages, as many as fifteen having been found in one spadeful of sod. (Pl. XXIX, Fig. 2.) Of the hundreds dug here but two or three proved to be of another species, although four other species were collected in the valley at this time. It was from

this location, about 400 miles by automobile from the laboratory, that most of the data on transporting nymphs alive were obtained.

The second location is a wild-grass meadow about 11 miles west of Lawrence on the road to Topeka, Kan. (Pl. XXVIII, Fig. 2.) The adults were observed ovipositing here, but no digging was done, as it was very stony soil and the meadow was mow land. This was a convenient place, however, to procure adults for cage experiments.

The third locality is a draw in the hills about one and a half miles southwest of Belvidere, Kan. It is noted for the adults collected there in 1923, when it was possible to capture 25 or 30 adults in a few strokes of the net. A visit to this same locality in 1925 failed, however, to reveal the nymphs one would naturally have expected to find. The adults had been many times thicker than in the locality in Scott county, where one could get but one or two specimens in twenty strokes of the net. This seeming high mortality may be accounted for by fires which destroy the eggs before hatching, or floods which bury and thus kill the vegetation of these flat valley-floor habitats.

HABITAT. This species is decidedly a lover of meadow land. It is practically never associated with trees. An unkempt roadside, small valleys among rocky hills, or any other land growing wild perennial grasses and weeds, unmowed and rarely burned over, makes an ideal habitat. Here both sexes find food in abundance and the females plenty of pithy stemmed weeds for oviposition, while the nymphs pass the long underground life feeding on the roots of the plants. (Pl. XXVIII, Fig. 2.)

BEHAVIOR. This is not what one would term a wild species, although during the heat of the day they take flight readily. The females are very tame while ovipositing, paying little attention to anything else. The stems upon which they are working may be carefully cut off and the specimens moved about at will for observation and photography without disturbing them in the least.

The best method to locate the adults when entering a new locality is by sweeping the vegetation with a net, as the specimens are small and colored very much the same as the plants upon which they live. Unlike most other cicadas the males do not sing loud enough to be heard for more than a few feet. It is possible when one becomes familiar with this species to walk through a likely place watching the hordes of insects fleeing ahead and to pick out the cicadas and often notice where they alight. This is usually not far away unless a strong wind is blowing. Walking toward the wind will often help, as the individuals will not fly so far against the wind as with it. When this method is being used, walking in a certain direction with regard to the light will also be found advantageous.

EMERGENCE. The emergence in the field begins the latter part of May and is well over by the first of July. They come out at night, as do other cicadas. The emergence hole is somewhat irregular, and only in rare cases does it show a tendency toward a cone (such as is made in some cases by the seventeen-year cicada). This is never raised more than a bare fraction of an inch above the level of the ground.

In cages the first emergence took place on June 11 and the last on July 2. Here, also, there was a tendency to raise the edges of the emergence chamber above the level of the surrounding soil in a few cases. The tunnel was constructed to within a fraction of an inch of the surface of the ground several

days before emergence in all cases observed, but no period of rest or fasting was detected. The nymphs seem to be active up to the time of emergence. One placed well toward the bottom of a small glass cage built a nice cell to the surface and emerged within ten days after being transplanted. This nymph was observed feeding on roots near the bottom of the cage the day before it came out.

A short time before emergence the eyes turn bright red, thus marking plainly those nymphs which are soon to appear as adults. In several instances after the eyes had turned red they again resumed a white color, and in a few days the nymph died. The most careful observations failed to reveal the cause of this relatively high mortality just before emergence time. In many cases the cell would have been completed to within a fraction of an inch of the top of the ground. Individuals have died in cages from which another nymph either had emerged, or did a few days later. Death could scarcely have been due to attack by external enemies, for it was foreshadowed by the loss of pigment in the eyes for some days before the individual succumbed. In fact, these individuals have been observed to be normally active and often belligerent when disturbed. Injury from transplanting would probably have been suspected, were it not for the fact that so large a number of empty shells had been found in cells near the surface, while digging for nymphs in the field, that it was considered that possibly these large forms had molted once in the cell. Rearing experiments show these must be the remains of nymphs which have died very much as the ones in captivity died. If red-eyed individuals are preserved the tarsal, claws, spines, etc., may be seen through the nymphal skin. Thus we have another mark of approaching maturity.

FEEDING. The adults in captivity feed within twenty-four hours after emerging. They feed frequently at all times of day. They have been observed on so many different hosts that it has been considered they will use almost any living plant in their locality. In captivity they have been seen feeding on oak and asparagus—two plants not in their regular habitat.

MATING. The mating of this species was not observed in the field. One female emerging from a cage mated with a male brought in from the field the next day and deposited eggs that same day. While this pair was in copula another male in the cage crawled to within an inch of them and sang persistently.

OVIPOSITION. Many females have been observed ovipositing in the field. As has been stated above, they are less wary than most species, and may often be carried about by removing the stem upon which they are working. They will oviposit in almost any green plant but will make a far greater series of nests in some of the perennial weeds with pithy stems. (Pl. XXX, Fig. 1.)

The mechanics of oviposition is the same as that already described. There appears to be no secretion either at the beginning of the nest or at the ending. Neither does the female attempt to replace the shredded tissues of the host plant when the nest is completed. This species oviposits freely in captivity. Numerous nests have been placed both in sweet clover and asparagus. As has already been stated, a female which emerged in captivity mated and laid eggs the next day.

NESTS. The nests are regularly placed in one row up and down the stem. (Pl. XXXII, Fig. 2.) More than one row is sometimes found, but this is probably due to different females having used the same stem. The number of nests in a series may vary from one to thirty according to the nature of the host, whether it is hard or soft, to the condition of the female, and to whether she is disturbed. The nests give the stems a roughened appearance, and when they are closely placed weaken the stem, but they do not kill it. The eggs in a nest vary in number, from three in hard stems like the compass plant (*Silphium laciniatum*) to twenty in the pithy stems of sweet clover. The arrangement of eggs in the nest varies also with the kind of material of the host. Often this species arranges its eggs in a vertical fan (Pl. XXXVIII, Fig. 4) instead of in the regular way (Pl. XXXI, Fig. 3).

LENGTH OF LIFE. In the field no data have been obtained as to the length of life of the adult. In cages they have been kept for about ten days. Since the female that emerged in captivity mated and laid eggs the next day, it is reasonable to assume they do not live a great while even under the most favorable conditions.

ENEMIES. The adult cicadas of this species fall easy victim to a great many predacious enemies. The dipterous family of robber flies, Asilidæ, is perhaps the arch enemy, as a great many large species of this group are very common throughout the habitat of *Melampsalta*. The cicada flies so slowly that it is easy prey for these hawks of the insect world.

A great many specimens, too, have been taken from spider webs where they have become entangled and then wound up with silken thread. Not uncommonly specimens have been seen in the jaws of certain of our large spiders, no web having been used in the capture.

Aside from the predacious enemies, *Melampsalta calliope* (Walk.) encounters numerous vicissitudes such as haymaking, fire and floods. Such conditions probably play the biggest role of all in excluding the species from many localities. Eggs laid in a wild hay meadow are very often destroyed by the mowing of the meadow before hatching time.

Fire is another big hazard which this species must run. An accidental fire in the meadow lands where *Melampsalta* has oviposited obliterates entirely the year's brood in that locality.

Floods are also a very real menace to broods in certain lowlands. Flat-bottomed draws surrounded by prairie-covered hills often furnish the habitat desired by this species. In times of freshets great amounts of soil are carried down and deposited in these locations, often entirely covering and thus killing the vegetation. This, of course, destroys any eggs which are in the present growth and starves the nymphs of other broods which are feeding on the roots.

EGGS. The eggs of *Melampsalta calliope* (Walk.) differ from the other species of cicadas in appearance only as to size. They are 1.7 mm. in length and 0.31 mm. in width. When laid they are white in color, changing to pink before hatching.

MATURATION. The egg stage is about two months. Before hatching red eyespots appear and later the entire egg becomes pink. Female cicadas were observed ovipositing during June, and the eggs hatched in August.

HATCHING. The hatching of the eggs takes place in August of the summer they are laid. It probably continues about a month. This was difficult to ascertain because the eggs shrivel with the withering of the host, so that it was impossible to bring quantities of stems into the laboratory for observation. The eggs do not seem to hatch as completely as those of some of the other species. Usually a few eggs in each nest appear shriveled. Probably the fact that they do not place a secretion in their nests after oviposition, but leave the eggs dependent upon the condition of the host, accounts for this loss.

The first nests of eggs found in June, 1925, were collected, packed in boxes and mailed to the laboratory. Examination a few days later revealed that the eggs were shriveling. The next attempt to secure the hatching of eggs was made August 14, 1925, when stems containing eggs were again mailed to the laboratory. These eggs showed red eyespots plainly, were pink in color, and the tarsal claws of the embryo could be seen through the eggshell. They reached the laboratory August 15. The foliage of the plants had not yet withered and the eggs seemed in perfect condition. A few eggs were hatching when they arrived, and they continued to hatch in the laboratory throughout the 15th and 16th. The hatch was regular in every way, appearing identical with all other species observed. For twenty-four hours these stems were kept in a closely covered jar to prevent withering of the hosts. The evening of August 16 the laboratory assistant was called out of town and the stems were placed in the open over a pot of perennial grass. Hence, no data were obtained as to how long eggs would have continued hatching in these cut stems if they could have been kept in humid conditions. Examination of the nests two weeks later showed that a large per cent of the eggs had shriveled instead of hatching. An attempt to find the tiny nymphs was made early in the spring of 1926 with no success, and fear was entertained that none of them had succeeded in finding food. However, another examination March 27, 1927, revealed four nymphs—three were third-instar nymphs and the fourth was still a second-instar nymph.

In the summer of 1926 numerous nests of eggs were obtained in plants in the outdoor insectary from adults in captivity. Since it was again necessary for the caretaker to be away during the time of hatching, large glass-sided cages were buried near these host plants in the hope of catching the tiny nymphs in them when they emerged. Time must be allowed before the success of these attempts can be determined because of the difficulty of finding first- or second-instar nymphs in large quantities of soil.

A number of newly laid eggs were removed from nests and placed on moist cellucotton in a vial. These eggs appeared to remain in good condition, but maturation was not completed. This stage of *Melampsalta calliope* (Walk.) is more difficult to study than of any other species observed because of the extreme susceptibility of the eggs to the condition of the host.

PARASITES. A number of chalcid parasites belonging to the genus *Syntomaspis* were bred from nests made in sweet-clover stems. These have been identified by A. B. Gahan as the same genus and species as previously bred from the eggs of *Tibicen aurifera* (Say). (Ann. Ent. Soc. of America, vol. XVIII, 1925, p. 483.)

NYMPHS.

FROM THE FIELD. Several hundred nymphs of *Melampsalta calliope* (Walk.) have been taken in the field. The greater part of these came from the locality in Scott county, Kansas. (Pl. XXIX, Fig. 1.) Interest in this locality was first aroused by the taking of adults of the species while sweeping in this glen. Although not many were taken in each series of sweepings, the adults were soon observed flying away as the collector walked through the weeds. Careful examination of the herbage soon disclosed large series of nests in many of the weeds. Attention was then directed to scanning the weeds carefully for a female in the act of ovipositing. In a few minutes one was located, and the process observed first with the naked eye and later with a small hand lens. When attention was directed to the hunting of this one insect, it was not difficult to find, and several were observed ovipositing and feeding on as many different types of wild plants. So gentle were they that observations and photographs were made with ease in the open. Since an hour or so of work had been awarded by success in obtaining data on feeding habits and oviposition of *Melampsalta calliope* (Walk.) it was decided to try digging for nymphs.

A site was chosen near a plant with old oviposition marks on it. These were in dead stems which had remained standing, while new nests were always in green tissue. Almost the first spadeful of dirt yielded nymphs, and as many as fifteen individuals have been found in one spade of sod. (Pl. XXIX, Fig. 2.)

Usually the cell of *Melampsalta calliope* (Walk.) is not over an inch long where food is plentiful, although, if the plant on which a nymph has been feeding has died, the cells may become burrows extending many inches. In either case it is usually a simple matter to find the occupant if a cell is discovered, and using care thus first to locate the cells greatly reduces the danger of injuring the nymphs. The following notes taken in the field on this first trip may be of interest:

"In digging for nymphs we soon came to recognize their burrows. The cells that contain the nymphs are usually only an inch or so long. One end is of the normal soil, while the other is stopped by some dirt cuttings which look much like fish-worm droppings. They occur mostly from six to ten inches beneath the surface. Only the largest specimens are found near the surface. These have large wing pads and doubtless would have emerged in a few days. One with large wing pads was down about eight inches, but it is different in coloring from those found near the top of the ground. We could arrive at no further conclusions as to age of the nymphs by the depth at which they occurred because all sizes were found at all depths. More nymphs are found where vegetation is thick. We could not tell which kind of vegetation they preferred. There was seemingly no difference or preference. A good many molted skins were found near the surface of the ground, which seems to demonstrate that the little fellow molts once after it has large wing pads."

From the first collection of nymphs made in June, 1925, about fifty specimens of all sizes were preserved in alcohol and as many more were packed in loose earth and mailed to the laboratory. When they arrived, two days later, just five specimens were uninjured. These all happened to be of the fifth stadium. Two of these were placed in a small glass-sided cage perhaps one-half inch thick with newly transplanted crab grass (*Digitaria sanguinalis*) as the host. Usually newly transplanted hosts make poor food for nymphs,

but so quickly does crab grass recover from being moved that these nymphs seemed to thrive from the first. They began working on their cells almost immediately when placed in the cages. These were soon completed one-half inch in diameter and two and a half to three inches in length, with the long axis in a vertical direction. Often the glass was allowed to form a part of the cell for weeks at a time. The extent of the cell could be seen readily in this small cage by the difference in appearance where the dirt had been pressed firmly against the glass in making it.

The other three nymphs, received uninjured in this lot, were transferred to a pot of native grass. This pot did not have sufficient drainage and a heavy rain drowned the nymphs.

A second attempt to transport *Melampsalta calliope* (Walk.) nymphs from Scott county was made in August, 1925. This time they were packed in roots and leaves. They were mailed as soon as dug and reached the laboratory the next day. Within twenty-four hours after leaving their cells in the field they were digging new homes in the laboratory. Nineteen individuals of this lot arrived uninjured. Most of these had formed cells in the dirt about them and were in good condition. Specimens which had been injured were preserved for laboratory use. Of those put in live cages, several were lost by experimenting with them in cages of wheat. However, some interesting observations were made on habits of digging and feeding in the cages of grasses. August 30, 1925, a third-instar nymph was observed digging its cell. It cut the dirt loose with the front claws, packed it on the postclypeus until it had a ball about as large in diameter as its head, then holding it in place with one front claw, it backed to a wider place in its cell and turned over ventrally, describing a partial somersault. By means of its two hind pair of legs—one pair up and one down—it crawled off in the opposite direction. This placed the ventral side up where it had been down before, but the nymph paid no attention whatever to this, crawling as easily one way as another. When it reached the opposite end of its cell it deposited the ball of mud and smoothed it down with its front claws. This was repeated over and over, the action being the same in every detail.

September 2, 1925, a cage was examined which contained a small fourth-instar nymph. The grass was dead. The nymph had burrowed from end to end of the cage in its search for food, and was trying vainly to go deeper in a lower corner. Another cage, in which the grass was dead, contained a fifth-instar nymph. When the glass was removed in order to transplant new grass the nymph behaved much as a human might during a violent earthquake. It crawled rapidly to the top of its tunnel, then hastened down halfway, stuck its head and front claws out of the opening in the cell and appeared to be trying to detect in some way what had caused the disturbance, and to show fight if it encountered anything. So threatening was its attitude that a stem of grass was held close to it in the opening. It grasped the stem firmly, apparently trying to mangle it. Its alarm was very real. When the transfer was complete and the cage closed, it immediately settled back in its cell and resumed normal activity.

On September 16, 1925, a fifth-instar nymph was observed feeding. It was so located that its beak could be seen plainly without removing the glass. It happened to be standing with head downward and remained in this position

feeding for forty-five minutes, holding very still. The front claws were suspended in the air, not grasping the root on which it was feeding.

A laboratory study of preserved material divided the nymphs into eight apparent sizes. Since it was impossible to prove what constituted a year's growth, or even to be sure what range of variation should be termed an instar, a series of experiments were planned to settle these points by rearing nymphs. A trip was made to Scott county, Kansas, in November, 1925, to obtain live material. This material was transported in layers of mud and live cages as described under technique of transporting live nymphs, page 162. There were no fatalities in transit. One hundred twenty-nine nymphs of the last four instars were collected. Eighty-nine of these were placed in a large pot of *Panicum virgatum* to insure future material. When the large pot was inverted on a table the contents remained intact, revealing almost a solid mass of roots, large and small, on the outside of the lump of dirt. (Pl. XXXIII, Fig. 3.) The nymphs were inserted in small holes made between the roots in the dirt and each cell capped with a flattened bit of mud. These nymphs were placed all around the pot and at varying depths, from three inches down to within an inch of the bottom. They were as follows: Size No. 8, 20 individuals; size No. 7. 25 individuals; size No. 6, 10 individuals; size No. 5, 20 individuals; size No. 4, 12 individuals. The sod was then replaced in the pot and left in the warm laboratory for 48 hours.

The remaining 42 nymphs were sorted according to apparent size, placed in cages, and records made of them. Only nymphs judged to be the same age were placed together. Usually not more than two fifth-instar nymphs were caged together, but as many as five or six of the small ones were put in the same cage. The host was orchard grass and had been growing for a month. The nymphs were kept in the laboratory for 48 hours. When examination showed that they had formed cells, they were buried in the open with the tops of cages even with surface of the ground and thinly covered with dead leaves.

These cages were unmolested until May 9, 1926, when they were taken into the laboratory for examination. A few nymphs were found dead where they had been planted; these were undoubtedly injured in collecting. A few others appeared to have died recently. In one cage the grass had died and the nymphs had starved to death. The soil was alive with other tiny animals, springtails, mites, fishworms, ants, sowbugs, etc. There was no evidence, however, that the cicadas had suffered from any of them. About 30 of the 42 original nymphs were found in the cages in apparently good condition.

June 1, 1926, while a search was being made in another locality for nymphs of another species, three fifth-instar nymphs of *Melampsalta calliope* (Walk.) were found. These presented one striking difference to those last observed in the cages. They all had bright red eyes. This suggested the possibility that time of emergence is foreshadowed by a change of color of the eyes of the nymphs. Accordingly, the cages of *Melampsalta calliope* (Walk.) were again examined. Not only did the nymphs called No. 8 have red eyes, but the eyes of all of those called No. 7 likewise had changed color. This indicated that all of the nymphs with large wing pads were the same age and would emerge during the summer. Consequently all cages containing these nymphs were covered with screen wire to prevent the escape of emerging nymphs. Most of

these individuals had completed cells very close to the surface of the soil, but in no case did they appear to be resting or fasting.

July 16, 1926, two weeks after the last adult had emerged in captivity, two of the nymphs labeled Nos. 5 and 6 were found transformed to last-instar nymphs. When specimens are examined in midwinter and have been molted for a considerable time it appears impossible that these fourth-instar nymphs could become fifth instars with a single molt, but when they are observed just before and after molting the change seems simple. Before molting the abdomen becomes very much distended. Immediately after molting the new fifth-instar nymph is noticeably smaller than other specimens which have been in this stage for some months. The abdomen is slightly distended toward the center and all color markings are very delicate, some of the lighter parts appearing almost transparent. The cast skins of these two nymphs were found, one at the top of a vertical burrow about one and a half inches long and one at one end of a horizontal burrow about one inch in length. Neither of these skins gave any evidence of having been attached to the walls of the cell before being shed. Another nymph, which was carefully observed in the evening of July 16, molted during the night and was again observed on the morning of July 17. At both times the nymph appeared active and normal in every way.

A careful examination of all cages containing smaller nymphs failed to reveal a single specimen. The condition of the soil in some of these gave evidence that the nymphs had been eaten by ants or other predacious animals.

On November 19 the last cage, containing what had been called a No. 5 nymph, was examined and the nymph found to be a very small, delicately colored, fifth-instar nymph. The cast skin was found buried only a fraction of an inch beneath the end of the burrow. The appearance of the nymph and the position of the cast skin led to the conjecture that it had molted quite recently. If this conjecture is true, there was a variation of about four months in the time of molting of the fourth-instar individuals into fifth instar. This variation may have been increased by the abnormal conditions in the cages, but the size of specimens collected in the field tends to show considerable difference even in nature. Of the specimens in cages all of those with large wing pads either emerged as adults or died, and all of those grouped as Nos. 5 and 6 either died or changed to the last stadium. This evidence removed all question as to there being more than the normal five instars common to the Homoptera, and in the case of *Melampsalta calliope* (Walk.), seemed to give not longer than a year as the length of any one stadium.

Melampsalta calliope (Walk.) has not been reared from egg to adult in the laboratory, but sufficient data have been obtained on the length of the various stadia to warrant some conclusions. Nymphs which emerged in August, 1925, were in the third stadium in March, 1927. Since it is known that nymphs other than the first instar normally molt in the summer, and that first-instar nymphs of some of the other species molt in the fall after emerging in the summer, it seems safe to conclude that *Melampsalta calliope* (Walk.) nymphs molt from first to second in the fall after hatching, from second to third the following summer, and each succeeding stadium extends throughout a year. This would give *Melampsalta calliope* (Walk.) a total life history of approximately four years.

DESCRIPTION OF INSTARS.

FIRST INSTAR. Length, 2 mm.

Color of the body pink, appendages white. Antennæ seven-segmented, almost parallel sided, the outer segments forming a sort of club. Eyes red spots of pigment beneath the epithelium. Tarsi two-segmented with two apical claws of about equal length. (Pl. XXXVIII, Fig. 6.) Apex of tibiæ with several large spines, none of them with setæ. Apex of front tibiæ produced into a bifid tooth, with a small median tooth and large posterior one almost as long as the tibiæ with a smaller notch on its cutting margin. Body sparsely covered with stiff hairs. Length of front femora, .2 mm., of the pronotum .25 mm. (Pl. XXXIX, Fig. 2.)

SECOND INSTAR. Length of entire body, 3.29 mm.; length of front femora, 0.3 mm.; length of pronotum, 0.4 mm.

Color creamy white. Antennæ five-segmented, elbowed at apex of first segment; tapering from base to tip. Eyes small swellings on side of head with row of stiff hairs extending vertically across them. Tarsi one-segmented, scarcely discernible on the front legs. Tarsal claws mere stubs, the posterior one the longer. (Pl. XXXVIII, Fig. 6.) Apex of middle and hind tibiæ with two setæ-bearing spines. Front tibia prolonged into a claw-like projection with a tooth on the anterior margin. A flat, platelike shearing organ developed just anterior to the middle spine on the front femur (the comb), has two distinct teeth besides the large apical one. (Pl. XXXVIII, Fig 1.) This organ is termed "the comb" by Marlatt in his work on the seventeen-year cicada, and hereafter will be known by that name. The posterior spine with a tooth at the base. Wing pads not yet visible. In general shape this instar very closely resembles the third and fourth. (Pl. XXXIX, Fig. 3.)

THIRD INSTAR. Length of entire body, 6.5 mm.; length of front femora, 0.65 mm.; length of front wing pad, 0.3 mm.; length of hind wing pad, 0.2 mm.

Color creamy white, shading into fuscous on anterior half; cutting parts of front legs darker. Antennæ six-segmented, tapering from base to tip, elbowed at apex of first joint. Eyes inconspicuous swellings on sides of head with a row of stiff hairs extending vertically across them. Tarsi one-segmented, those of front legs scarcely discernible, middle and hind legs with two horny rudiments of tarsal claws, the anterior one the shorter. Apex of middle and hind tibiæ with two setæ-bearing spines. (Pl. XXXVIII, Fig. 6.) Front tibia with large notch near apex on cutting edge. Comb of front femur with three distinct teeth. (Pl. XXXVIII, Fig. 1.) Posterior tooth of femur bifid, distinctly built for digging. Wing pads barely discernible. (Pl. XXXIX, Fig. 4.)

FOURTH INSTAR. Length of entire body, 7-10 mm.; length of front femora, 1.2 mm.; length of front wing pad, 1 mm.; length of hind wing pad, 0.75 mm.

Color creamy white with cutting parts of front legs fuscous. Apex of middle and hind femur and apical end of some of antennal joints with brown bands. Antennæ seven-segmented, tapering from base to apex, elbowed at apex of first segment. Eyes inconspicuous with a row of stiff hairs extending vertically across them. Tarsi one-segmented; that of front leg hardly discernible, apparently without claws, those of the middle and hind legs bearing two horny projections, the outer the smaller. Apex of middle and hind tibiæ with two

setæ-bearing spines. Front tibia clawlike with a blunt tooth well toward the tip. Comb of front femora with three distinct teeth besides the blunt apical one. (Pl. XXXVIII, Figs. 1 and 7.) Middle tooth of about same height as comb. (Pl. XXXIX, Fig. 5.)

FIFTH INSTAR. Length of entire body, 10-18 mm.; length of front femora 1.8 mm.; length of front wing pad, 2.3 mm.; length of hind wing pad, 2 mm.

The males tend to be slightly smaller than the females. General color runs from almost white to fairly dark brown. Posterior margin of tergites usually bordered with a darker band of brown, although in some specimens this is scarcely noticeable. Antennæ usually seven-segmented. Tarsi two-segmented, all distinct, the front ones turned back on the inside of tibia. (Pl. XXXVIII, Fig. 8.) Tarsal claws two, unequal in length, the outer much the shorter. Setæ-bearing spines at apex of middle and hind tibiæ, three in number. (Pl. XXXVIII, Fig. 6.) Eyes fairly prominent, becoming red just before emergence; posterior half sparsely covered with hairs. Comb of the front femur with five teeth, the largest one not much higher than the others. (Pl. XXXVIII, Fig. 1.) An indication only of a lateral tooth on tibia. General shape when compared with the fourth instar more cylindrical, with the three divisions of the body more nearly equal in diameter and their sides more nearly parallel. (Pl. XXXIX, Fig. 6.)

Proarna venosa (Uhler).

ADULT. *Proarna venosa* (Uhl.) is the smallest species which occurs in Kansas. In color it is gray with brown markings. Some specimens superficially resembled *Melampsalta calliope* (Walk.). It occurs practically throughout the state, but not in such great numbers as does the above species. The habitat is a high dry hillside or hilltop, almost too barren to support vegetation. One cannot help but wonder sometimes what the adults feed upon and how the nymphs can exist in such rocky soil. In Scott county, Kansas, near the locality where *Melampsalta calliope* (Walk.) was taken in such numbers *Proarna venosa* (Uhl.) was found in reasonable numbers about one-half way to the top of the hills which border Beaver creek. (Pl. XXIX, Fig. 1.) It was here that observations on feeding and egg laying were made, and the nymphs were collected.

BEHAVIOR. This species is a very sluggish insect, hardly moving from beneath the feet. It is usually discovered by sweeping the scanty vegetation. The song of the male is very shrill, but can be heard only a few feet, so it is not of much value in collecting. The greenish-gray appearance of the body gives the individuals excellent protection because of its resemblance to the color of the host plants. The most expeditious method of locating individuals for study in the field is to follow the specimens which fly ahead as the observer walks through the grass. This is readily accomplished, as they do not fly far. They feed frequently. Females have been observed trying to feed on the stems on which they were ovipositing.

OVIPOSITION. So tame is this species that it is a simple matter to make observations once a female is located. The following extract taken from the field notebook gives rather a vivid picture of her activities:

"June 24, found *Proarna venosa* (Uhl.) female at 8:15 a.m. At 8:26 she started ovipositing after moving around and finding a suitable stem of dead

grass. The first nest was finished in seven minutes, or at 8:33, and another started immediately. The second was completed at 8:38, and the third begun immediately. This was finished at 8:48, and the fourth begun without delay—it being finished at 8:55. She then went around the stem one-fourth way and began the fifth at 8:56. She became startled at 8:59 and flew to a bunch of grass without any old stems. The stem in which she had been ovipositing was cut off and the end of it held down where she was clambering around in the blades of grass, and she immediately crawled upon it. She explored this a short time and then started to oviposit. Since the wind was so strong, the stem was carried over behind a cliff without disturbing the process. She was examined minutely with a hand lens, and held, with a notebook for a background, for a picture, seemingly without disturbing her in the least.

"In starting the nest, the body is curved to about a right angle and the ovipositor to somewhat less than a right angle, and a little foamy fluid is exuded on the stem. The ovipositor then begins to rotate in this spot of liquid with the saw-toothed valves working back and forth, first one and then the other. The teeth cut to shreds the tissue of the stem. When the ovipositor has been inserted full length the eggs are placed. Each egg can be plainly seen as it passes down the ovipositor. When the last egg has been laid the opening is filled with this same foamy material as was used at the beginning. She makes very little attempt to pat down the torn tissues of the stem, but moves almost immediately to a new place. This is practically one ovipositor length from the old one."

The eggs are laid in almost any dead plant stems that are at hand. In Scott county the dry fruiting stalks of a native prairie grass were favorite places.

NESTS. The nests are arranged in a single row lengthwise of the stem. From one to a dozen or more nests may be made in a series. The opening is very small and inconspicuous. Collecting them is facilitated by holding the grass stems in a loose bunch, and looking down into them. The observer detects the series of nests as white saw-teeth on the sides of the stems. Three or four small, white eggs are placed in a single row in a nest. They are 1.52 mm. long and .36 mm. wide. Unlike *Melampsalta calliope* (Walk.) these eggs remain white until hatching takes place.

In 1925 the eggs collected the week of June 24 showed red eyespots August 5, and postnatal molts were found about the nests August 10. The first nymphs hatched in the laboratory August 16, and hatching continued until September 27. Whether this relatively long hatching period was due to laboratory conditions or to differences in the time of oviposition, or whether it is a normal variation for *Proarna venosa* (Uhl.) has not been determined.

These eggs hatch the same as other species noted, and the nymphs are equally active and capable of building a home and finding food, but they are noticeably smaller than any other nymphs observed.

The first-instar nymphs transplanted in captivity appear to have died for want of food or to have been eaten by predacious enemies before molting. This total loss of considerable material is attributed largely to the unhealthy condition of the hosts used. At the time of this hatching, experiments were being conducted with some of the native western Kansas grasses, which did not thrive under insectary conditions. Also, surviving nymphs may have been destroyed by an attempt to find them in the soil, for it has since been admitted to be practically impossible to locate the first-instar nymphs in large quantities of earth.

Numerous excavations were made beneath bunches of grass which showed old oviposition marks without yielding any nymphs. This, in some measure was due to the very rocky condition of the soil. However, by prolonged digging beneath and around yucca plants, about 30 were obtained. Three of these belonged to the third instar, 22 to the fourth and 11 to the fifth. No second-instar nymphs were found.

FIRST INSTAR. Length of entire body, 1.6 mm.; length of front femur, 0.2 mm.

Color of the body creamy white with the cutting parts of front legs darker. Antennæ usually six-segmented. Eyes red pigmented. Tarsi two-jointed with two tarsal claws, one much longer than the other. Middle and hind tibiæ with scattered heavy spines without setæ. Front tibia beaklike, with two teeth on the cutting margin. Front femur with a median sharp spine and a posterior one which is long and heavy with a tooth on the cutting surface. Body sparsely covered with stiff hairs. (Pl. XL, Fig. 2.)

SECOND INSTAR. This instar has not been seen.

THIRD INSTAR. Length of entire body, 6 mm.; length of front femora, 0.7 mm.; length of front wing pad, 0.4 mm.; length of hind wing pad, .3 mm.

Color creamy white, slightly darker on cutting parts of front legs. Body with a few scattered hairs. Antennæ usually eight-segmented, tapering from base to tip, elbowed at apex of first joint. Tarsi one-segmented, that of front leg indistinguishable on anterior margin of tibia, middle and hind tarsi with two apical claws of about equal length. Apex of middle and hind tibiæ with three setæ-bearing spines. Wing pads plainly seen as outpouchings of meso thorax and metathorax. Eyes represented by slight swellings on side of head with six small to large hairs scattered at random about its surface. Comb of front femora with three distinct teeth besides the blunt apical one. Ventral cutting edge of tibia with one notch. (Pl. XL, Fig. 3.)

FOURTH INSTAR. Length of entire body, 6.75 to 10 mm.; length of front femur, 1.25 mm.; length of front wing pad, 1 mm.; length of hind wing pad 0.6 mm.

Color creamy white tinged with brown, margins of cutting parts of foreleg darkened. Antennæ usually eight-segmented, tapering from base to tip, elbowed at apex of first segment. Eyes less in evidence than in fifth instar, sparcely set with hairs. Tarsi one-segmented with two tarsal claws of almost equal length; that of the front legs very difficult to see with the naked eye so closely appressed is it to the inside of the front tibia. Comb of the front femur with three well-defined teeth besides the blunt apical one; some show a very small fourth tooth. Front tibiæ with but one notch on ventral margin, apex of middle and hind tibiæ with three setæ-bearing spines. Each segment of abdomen with sparsely set row of hairs. (Pl. XL, Fig. 4.)

FIFTH INSTAR. Length of entire body, 16 mm.; length of front femur, 2.3 mm.; length of front wing pad, 4.2 mm.; length of hind wing pad, 2.2 mm. (Pl. XL, Fig. 5.)

Color creamy white with appendages and borders of body segments more or less tinged with brown. Antennæ usually nine-segmented, tapering from base to tip, elbowed at apex of first joint. Eyes fairly well developed, with a band of scattered hairs. Tarsi two-segmented, of normal size, with claws of unequal length. Apex of middle and hind tibiæ with three setæ-bearing spines.

This species differs from all others observed in not increasing the number of these spines with this molt. Front tibiæ with one tooth on ventral cutting side, middle tooth of femur large, considerably longer than the comb, a character which separates the nymphs of this species from those of *Melampsalta calliope* (Walk.). Comb with four well-defined teeth besides blunt apical one.

Cicada hieroglyphica Say.

ADULT. This is a rather small, green, black and straw-colored species, measuring 20 to 25 mm. in length. The colors of the body are so arranged as to blend almost perfectly with the lichen-covered trunks of the oak trees upon which they are found, making the individuals very difficult to find. The wings are held less rooflike than in our other species of cicadas, giving them a flattened appearance. The most striking character is the transparency of the abdomen when viewed with transmitted light.

DISTRIBUTION AND HABITAT. So far as is known this species is limited in distribution to blackjack (*Quercus marilandica*) and post oak (*Quercus stellatus*) groves in the southeastern corner of the state. Most of the data were obtained near the nursery of Mr. John Wilson, four and one-half miles southwest of Elk City, Kan. This nursery is located in some oak-covered hills, and made an ideal place to study a large brood which occurred there this past summer (1926). The only other locality where material was obtained was an oak grove twelve miles east of Columbus, Kan. This latter place was visited on June 6, 1926, when thirty nymphs of the three last instars were dug from the sandy soil beneath the oak trees.

No adults were present at this time. However, a few weeks later these woods were ringing with the songs of the males. While all other data obtained would lead to the conjecture that cicadas are not specific feeders, this species shows such a marked preference for the habitat described that one is forced to admit that if oak is not essential to life, at least it is greatly preferred. In both localities other trees surrounding the oak or between groves of it would yield no *Cicada hieroglyphica* Say.

Another element of interest in the habitat is the nature of the soil. In both localities studied the soil from which these cicadas emerge is almost pure sand. Whether it is the oak trees or the sandy soil they prefer so decidedly has not been determined; but the two habitats were so similar and the boundary so marked that it seems scarcely probable that it is merely coincident.

EMERGENCE. This species begins emerging about June 7, and specimens have been noted as late as August 7. They appear in greatest numbers about the first of July. The act of emergence has not been witnessed, but the appearance and position of the exuviæ and of the emergence holes leads one to conjecture that it is essentially the same as of other species of cicadas. The cast skins have been found in greatest numbers on the under sides of the leaves and branches of small oaks only two or three feet above the surface of the ground. This locality, near Elk City, is overgrown with these small oaks which come up everywhere from the roots of old stumps, making practically a solid mat of brush, so that it is difficult to observe the ground or to find the cast skins.

FEEDING. *Cicada hieroglyphica* Say in live cages fed frequently on oak twigs. No other host has been tried.

MATING. Matings have been observed both in the field and in live cages. Copula takes place as in all other species noted.

OVIPOSITION. So wary is this species, and so tiny and obscure are the nests, that much time was spent before any data were obtained on this phase of the life cycle. Although camp was pitched in the midst of oak timber which fairly rang with the songs of the males, and three days were spent, June 22 to 25, collecting and studying them both in the open and in cages, not a single nest was located. Fifty-one adults were confined in a mosquito-netting cage over live oak, but none of the females were seen to oviposit. It seems possible that this very flighty species may not oviposit in captivity as do many of the other species. It is considered, however, that this failure was due to the fact that the females were not yet fully matured.

A second attempt was made July 3 to obtain data on the oviposition. Even then the most diligent search by two collectors was not rewarded for several hours. Perhaps half a dozen females were spotted in the act of egg laying within the next day. The most cautious attempts to approach near enough to observe the process, however, resulted in disturbing them. It was noted that dead twigs were used exclusively for oviposition and the nests were found in the limbs from which the females had flown. It was then relatively easy, by diligent search along the small partially decayed twigs protruding from the main trunk of the tree to collect the limbs bearing the nests. These stubby limbs are characteristic of *Quercus marilandica.* (Pl. XXXIV, Fig. 2.) A goodly number of nests were found and brought into the laboratory for hatching.

NESTS. The nests are scattered at random on the twigs and are so small and carefully sealed shut that they often cannot be detected with the naked eye. In fact, nests have been cut into unexpectedly while the observer was dissecting a twig under the binocular. The decayed nature of the bark adds to the difficulty of finding the nests.

The eggs are invariably three in each nest, arranged in almost single file, with enough space between the last egg and the nest opening for another egg. The nest is filled with an excretion which appears, after drying, very much as empty broken eggshells might.

EGGS. The eggs, when laid, appear identical with all other cicada eggs observed. They are 1.6 mm. long and .4 mm. wide. In about seven weeks after they are deposited red eyespots appear, and a few days later the eggs hatch. The total incubation period is about two months.

The method of hatching and behavior of the nymphs is identical with that of other species described. The hatch appeared to be complete so far as observed. No parasites were reared from these nests. In fact, it would be difficult to prove that animals found in the limbs had been parasitic on the eggs of *Cicada hieroglyphica* Say, for the entire twig often reminded one of a tenement district. Nests of other species of cicadas, and evidences of innumerable other kinds of minute life were plentiful. The scarcity of the eggs was disappointing. About sixty nymphs were plated and perhaps a dozen preserved for study between September first and fifth.

NYMPHS. The nymphs hatched in the laboratory were transplanted to a

small glass-sided cage which was well filled with orchard grass. This cage was buried in sand in the laboratory. October 10, 1926, an examination of part of the dirt in this cage revealed one nymph apparently not much larger than when hatched, but alive and active. It was returned to its cell and the remaining soil unmolested. Later the cage was buried with the other plate cages out of doors. This bit of evidence would lend encouragement to the hope that these nymphs will live on grass roots.

Other rearing experiments on nymphs of *Cicada hieroglyphica* Say are lacking. The nymphs in the field were so scattered and the labor of obtaining them so great that it seemed impractical to risk losing the material by attempting to keep it alive during the excessive heat and with the poor facilities at hand at the time. However, in the light of knowledge gained from rearing nymphs of other species, the examination of nymphs in the laboratory revealed a part of the story.

DIGGING FOR THE NYMPHS. Extensive digging was done on Mr. Wilson's place at Elk City, and perhaps 100 nymphs were found. The equipment for and technique of digging for nymphs were the same as used in collecting other species. The nymphs were found more frequently on the north side of very large trees as close to the trunk as it was practical to dig. They occurred usually from four to twelve inches beneath the surface. Few cells were seen because the soil was so sandy that the least disturbance would completely wreck them. The evidence obtained, however, indicates that they are not unlike those of other species.

Material could easily be sorted into five instars (four instars from the material dug, as the first-instar nymphs were not found). In addition, one could distinguish between the nymphs newly molted into the fifth instar and those which were soon to emerge as adults. Nymphs between these two extremes could not accurately be placed in either group. No attempt is made to estimate the length of time required for any one instar or for the total life cycle.

FIRST INSTAR. Length of entire body, 1.6 mm.; length of front femur, 0.26 mm.; length of pronotum, 0.28 mm.

Color creamy white, anterior half of body and legs amber. Antennæ usually six-segmented. (Pl. XLII, Fig 1.) First segment short and thick, second slightly longer than first, almost parallel-sided; third half as long as second; fourth slightly longer than third; fifth same length as third; sixth oval in shape, pointed at tip, a little longer than fourth. Eyes represented by small spots of black pigment beneath the surface. Tarsi two-segmented, tarsal claws two, long, slender, of unequal length, anterior one the shorter. (Pl. XLII, Fig. 2.) Tibia with three nonsetæ-bearing spines at apex. Front tibia produced into a sharp, clawlike organ with a sharp tooth on its cutting margin. Anterior femur without comb; middle tooth small, sharp; posterior one long, with a small notch on its cutting margin. Whole body sparsely set with stiff hairs. (Pl. XLI, Fig. 2.)

SECOND INSTAR. Length of entire body, 4 mm.; length of front femur, 0.5 mm.; length of pronotum, 0.6 mm.

Color of body creamy white, anterior half and legs darker. Eyes represented by swellings on side of head, covered on posterior half by hairs. Antennæ usually six-segmented (Pl. XLII, Fig. 1.), three apical segments and apical half of third somewhat inflated. Tarsi one-segmented, those of the front legs

reduced to the merest rudiments, middle and hind legs with two tarsal claws of unequal length. Middle and hind tibiæ with three setæ-bearing spines (Pl. XLII, Fig. 2); front tibia beak-shaped, no teeth. Comb appears on the front femur with two distinct teeth on the cutting edge, posterior tooth large with no distinct tooth on its inner margin. Wing pads barely discernible. (Pl. XLI, Fig. 3.)

THIRD INSTAR. Length of entire body, 4.5 to 6.2 mm.; length of front femur, 1 mm.; length of front wing pad, 0.4 mm.; length of hind wing pad, 0.3 mm.

Color creamy white, shading into light brown on anterior half, cutting parts of front legs and apices of other legs. Eyes small swellings on side of head, posterior half sparsely covered with hairs. Antennæ usually seven-segmented (Pl. XLII, Fig. 1). Segments 4, 5, 6, 7 slightly inflated. Tarsi one-segmented, that of the front leg very small, two tarsal claws of unequal length. Middle and hind tibiæ with three setæ-bearing spines (Pl. XLII, Fig. 2), front tibia beak-shaped, with no teeth on inner margin. Comb of front femur with three teeth, besides blunt apical one (Pl. XXXVIII, Fig. 2); posterior tooth large with very small tooth near base. (Pl. XLI, Fig. 4.)

FOURTH INSTAR. Length of entire body, 7.3 to 11.5 mm.; length of front femur, 2 mm.; length of hind wing pad, 1 mm.; length of front wing pad, 1.5 mm.; length of pronotum, 2 mm.

Color creamy white shading to light brown on anterior parts; cutting parts of front legs and certain ventral sclerites fuscous. Eyes inconspicuous enlargments on side of head; hairy on posterior half. Antennæ usually eight-segmented, from third to tip tending to be inflated. (Pl. XLII, Fig. 1.) Tarsi one-segmented, exceedingly small on front legs. Apex of middle and hind tibiæ with three setæ-bearing spines. (Pl. XLII, Fig. 2.) Front tibiæ break-like; no teeth. Comb of front femur with four teeth (Pl. XXXVIII, Fig. 2), posterior tooth with small notch on inside. (Pl. XLI, Fig. 5.)

FIFTH INSTAR. Length of entire body, 12-20 mm.; length of front femur, 3.2 mm.; length of front wing pad, 6.5 mm.; length of hind wing pad, 3.6 mm.; length of pronotum, 4.3 mm.

Color creamy white, posterior borders of pronotum wing pads and abdominal segments fuscous. Cutting parts of front legs almost black. Antennæ usually eight-segmented; segments 4, 5 and 6 inflated (Pl. XLII, Fig. 1); fourth sometimes black. Postclypeus of peculiar rectangular shape. (Pl. XLI, Fig. 6.) Eyes large, projecting, posterior half sparsely covered with hairs. Tarsi two-segmented with two unequal apical claws. (Pl. XLII, Fig. 2.) Apex of middle and hind tibiæ with five setæ-bearing spines, front tibiæ beak-shaped with no spines or teeth on the cutting margin. Front tarsi bent back on inner margin of tibiæ. Comb of front femur with six well-developed teeth besides the blunt apical one. (Pl. XXXVIII, Fig. 2.) Middle tooth extends at a different angle; posterior tooth large, sharp, with an indication of a tooth on inner margin. Wing pads well developed. (Pl. XLI, Fig. 6.)

Tibicen aurifera (Say).

ADULT. *Tibicen aurifera* (Say) is one of the smaller species of this genus, measuring from 23 to 26 mm. in length. In color it ranges from green and black to almost orange and black. Freshly emerged specimens are often covered with long, golden-colored pile.

DISTRIBUTION. This species is found over the eastern third of the state, but not in definite broods any one year. It occurred over as large an area this past summer (1926) as it has for the past ten years. The special locality from which most of the data have been taken is a hillside one mile northwest of Midland, Kan.

HABITAT. *Tibicen aurifera* (Say) is most frequently found in small grass-covered areas containing shrubs. Often this habitat is near trees, and the males may be heard singing in them, too. While the largest number of nests taken have been in the hollow stems of panic grass (*Panicum virgatum*), they have also been found in other large grasses, in weeds, and in sumac (*Rus glabra* L.) which is a very common host. Where the latter is used, the nests are placed in the dead ends of twigs. The species is easily located by the song of the males. The adults are not wild, and hence are easily taken with the net. Although the male may be heard singing in trees, the female rarely oviposits in them. The individuals of this species are usually darker than their hosts and are comparatively easily seen.

EMERGENCE. The latter part of July *Tibicen aurifera* (Say) begins to emerge. It is, however, a late summer species, usually occurring in greatest numbers in September. Most of the observations on oviposition, etc., have been made during this month. In fact, it is among the last species to cease singing in the fall.

FEEDING AND MATING. The adults feed often in captivity, very much as any of the other species. Mating was observed on a compass plant (*Silphium laciniatum* L.) at Garnett, Kan., September 7, 1926. The individuals were end to end and remaining quiet during the making of a photograph. (Pl. XXXIV, Fig. 1.)

OVIPOSITION. (Pl. XXX, Fig. 3.) It was the finding of *Tibicen aurifera* (Say) ovipositing at the location northwest of Midland that first aroused my interest in the life histories of cicadas. The female seals the nest with an excretion, expending considerable time patting the torn tissue into place with the sheathes of the ovipositor.

NESTS. The nests are placed in a single row lengthwise of the stem. (Pl. XXXI, Figs. 1 and 4.) They are about the length of the ovipositor apart, and are separated by a little torn tissue. There may be from one to eighteen nests in a series. As has been stated above, the nest is neatly closed, leaving only a small mark on the stem. In grasses these nests are placed in the fruiting stalk. They do not injure the plant, in fact, they do not even weaken it materially. Normally the eggs are placed in two rows. Usually eight to twelve occur in a nest, but as many as twenty-two have been found.

EGGS. (Pl. XXXI, Fig. 3.) The eggs are 1.8 mm. long and 0.52 mm. wide. They remain white until hatched. Red eyespots appear during the second week in June, and hatching begins about June 16. This makes the egg stage at least nine months. Unlike most of the eggs which hatch the same season

Tibicen aurifera (Say) has a short hatching period. Within two weeks after the first nymph wriggles out, all have emerged. Practically every egg hatches which has not been parasitized, even to the occasional good egg in a nest where all others have been consumed.

PARASITES. Often as high as fifty per cent of the nests of this species are parasitized. A small metallic-green hymenopteron belonging to the genus *Syntomaspis* lays a single egg in the nest and the grub feeds on the eggs. (Pl. XXXI, Fig. 2.) Usually all the eggs in one nest are consumed by one grub, but occasionally in a large nest a few are uninjured. The grub obtains its growth and spends many weeks in a resting stage before pupating. In a few days after pupating, it emerges. In nature this emergence is timed nicely to coincide with the oviposition time of the cicada. In the laboratory the parasites have been known to emerge as early as May 7.

Some doubt has been expressed by hymenopterists as to the accuracy of the above data, but parasites have been observed in the field, and rearing has been done repeatedly under conditions which would allow no mistake as to identity. While the actual act of oviposition of the parasite in the field has not been observed, it is interesting to note that Fabre, writing in Souvenirs Entomologiques, page 272, recorded having observed a small hymenopterous parasite which he described as a chalcid 4-5 mm. long, black, with knotty antennæ increasing in size toward the end, and a long ovipositor situated toward the middle of the abdomen. He also states that in laying its eggs this impostor does not use the entrance to the nest made by the cicada but inserts its eggs through the solid wall of the stem and that the parasite subsists on the whole nest of a dozen cicada eggs. He did not collect the parasite, so could not learn its identity. He suggested that it might be new. More interesting still is the fact that Reaumur, writing in 1740, described virtually the same phenomena.

HATCHING. Just why it should have been difficult to learn to obtain the emerging nymphs cannot be explained unless because of so long an egg stage. Whatever the explanation, it must be admitted that bundles of stems containing eggs of this species and others were kept for months, only to let the nymphs emerge unobserved before the technique of obtaining them was perfected. The first success was in working with this species, and was somewhat of an accident. When red eyespots were observed the eggs were examined daily. On June 16 the stems containing the eggs were moistened because they had been kept dry for a few days while transferring from one laboratory to another. The stems had been left in the laboratory for a few minutes while further observations were made on a nest under the binocular. When the observer turned to remove the lot to the open again, they were found covered with many tiny, white nymphs. The wetting, together with the warmth of midday in June, had produced a large hatch. The chance circumstance gave the essentials of hatching eggs in the laboratory. Referring again to Fabre, one notes a similar experience. Having tried in vain repeatedly for two years to find the nymphs emerging, and finally, thoroughly discouraged, he laid a bundle of twigs on a chair, to be near his hand, and accidentally in front of his fire in the open hearth, while he made one last search in the twigs with his glass. When he turned to the chair to take up another twig, he found the nymphs emerging from the warmed nests by the hundreds.

NYMPHS. A year before any data had been obtained on the hatching of nymphs, a bundle of stems bearing *Tibicen aurifera* (Say) was placed over a large pot of *Panicum virgatum* and the eggs allowed to hatch naturally and the nymphs find their own way to food and shelter. Nothing was done to the sod for about eleven months, when the soil was removed by inverting the pot on a table and a search made for nymphs. By tearing about two-thirds of the root mass and soil into fine particles eleven nymphs were found. These were tiny white creatures 3 mm. in length which appeared to have many years to grow before they could emerge as adults. This proved beyond a reasonable doubt that *Tibicen aurifera* (Say) at least, had a relatively long life cycle. With *Magicicada septendecim* (Linn.) requiring seventeen years to complete its life and *Tibicen aurifera* (Say) giving evidence of requiring several years, little ground was left for belief in the popular statement, which so many authors had made, that the other species of cicadas probably develop in from one to two years. It was this information which caused the experiments to be started to obtain more suitable live cages, and some method of reducing the high mortality of nymphs during the first year.

Repeated efforts have been made to obtain nymphs in the field by digging on the hillside near Midland. A few nymphs have been obtained on many occasions. But since the first attempts at rearing nymphs were made with this species, it is not surprising that many were lost.

Observations were made, however, on the digging and feeding habits, and numerous hosts have proved satisfactory. Given sufficient food these nymphs form cells from an inch to two inches in length and large enough to allow freedom of motion of the legs. If the host thrives, they will remain in the same cell indefinitely, moving about very little. Even fifth-instar nymphs have been kept for months in cages little thicker than their cells. However, if the host dies, the nymph makes a heroic search for food. Third-instar nymphs have been observed to mine the dirt from end to end of a glass cage. A fifth-instar nymph, living in a large flower pot, was found to have tunneled the bottom half of the dirt thoroughly in search of food when the host had died. He was found in the bottom of the pot. When placed in a hole near live roots he simply completed his cell and remained for weeks where he had been placed. The only actual data on the length of the stadium that have been obtained is that the fifth requires more than one year for completion. The length of the first three stadia was determined approximately from the nymphs reared from eggs in the large pot referred to above. The first instar changes into the second sometime the first summer, the second into the third the second summer, and the third into the fourth the third summer. Thus, counting from the time the eggs were laid to the beginning of the fourth stadium, we have a period of three years. Definite data cannot be given as to the length of the fourth and fifth stadia at this time.

FIRST INSTAR. Length of the entire body, 1.8 mm.; length of front femur, 0.29 mm.; length of pronotum, 0.3 mm.

Color creamy white; digging parts of front legs fuscous. Antennæ usually seven-segmented, almost same size throughout. Eyes small, red granular pigmented. All tarsi two segmented with two tarsal claws of about equal length. Apex of middle and hind tibiæ with some large spines but no setæ;

apex of front tibia produced into a beak-like projection with two teeth on its anterior margin. Anterior femur with one small middle spine and a large, somewhat bifid posterior one. Body and appendages with the usual long, stiff hairs and spines. (Pl. XLIII, Fig. 1.)

SECOND INSTAR. Length of the entire body, 4 mm.; length of front femur, 0.5 mm.; length of pronotum, 0.6 mm.

Color creamy white to fuscous on cutting parts of front legs. Antennæ usually seven-segmented, tapering from base to tip; elbowed at apex of first segment. Eyes mere swellings on side of head, set on posterior half with sparse stiff hairs. Tarsi one-segmented; those of middle and hind legs with two claws, the anterior one slightly shorter; tarsi of front legs closely appressed to anterior surface of tibia, very small, scarcely discernible as such. Apex of middle and hind tibiæ with three setæ-bearing spines. Front tibia beaklike, bifid at tip and a slight sinuation at location of two small teeth in third instar. Comb of front femur with two distinct teeth besides blunt apical one, median tooth of about same height as comb; posterior tooth large, with a medium-sized tooth on its inner surface. Slight indication of wing pads. (Pl. XLIII, Fig. 2.)

THIRD INSTAR. Length of entire body, 7 mm.; length of front femora, 1 mm.; length of front wing pad, 1.2 mm.; length of hind wing pad, 0.3 mm.; length of pronotum, 1.2 mm.

Color creamy white, fuscous at apex of leg segments and cutting parts of front legs. Antennæ usually eight-segmented; outer two very closely joined. Eyes almost as in the second instar, slightly larger. Tarsi one-segmented; front one hardly distinguishable from side of tibia; middle and hind ones with two claws of almost equal length. Apex of middle and hind tibiæ with three setæ-bearing spines. Front tibia beaklike with three teeth—one large and two small ones. Comb of front femur with three distinct teeth, besides blunt apical one; middle tooth of about same height as comb; posterior tooth large, bifid. Wing pads discernible as small outpouchings of meso- and metanotum. (Pl. XLIII, Fig. 3.)

FOURTH INSTAR. Length of entire body, 8-15 mm.; length of front femur, 3.3 mm.; length of front wing pads, 2 mm.; length of hind wing pads, 1.5 mm.

General color creamy white turning to brownish on head, thorax and legs. Apices of leg segments, especially cutting parts of front legs, edged with black. Antennæ usually eight-segmented, smaller but of same general shape as that of fifth instar. Tarsi one-segmented, the middle and hind ones bearing two claws of unequal size; the front tarsi reduced to a small V-shaped segment with no sign of claws, so deeply embedded on the anterior side of the tibia that it can hardly be seen. Apex of middle and hind tibiæ with three setæ-bearing spines on anterior-ventral margin. Comb of front femora about as in fifth instar, but with only five main teeth. (Pl. XLIII, Fig. 4.)

FIFTH INSTAR. Length of entire body, about 20 mm.; length of front femur, 4.25 mm.; length of front wing pad, 7.75 mm.; length of hind wing pad, 5 mm.

General color brown with posterior borders of abdominal tergites, mesonotum and metanotum much darker. Apices of leg segments narrowly edged with black, also gonapophyses. Antennæ usually nine-segmented, segments parallel-sided growing smaller from base to tip. Apices of some segments may be edged

with black. Tarsi all normal and two-segmented, bearing two claws, anterior one one-fourth the size of posterior, the latter slightly longer than the first tarsal segment. Tarsi of front legs well developed, turned back on anterior margin of tibia. Apex of middle and hind tibiæ with four setæ-bearing spines on anterior ventral margin. Front tibia bifid at apex. Comb of front femur with six teeth along its outer margin. (Pl. XLIII, Fig. 5.)

Tibicen vitripennis (Say).

ADULT. *Tibicen vitripennis* (Say) is colored much the same as *Tibicen aurifera* (Say) and is about the same size, with the exception that it is slightly more slender. The two species may be separated by the following characters: Uncus wishbone shaped, *vitripennis* (Say); uncus not wishbone shaped, *aurifera* (Say).

DISTRIBUTION. Roughly speaking, this species has been taken over the eastern half of the state. It occurs in greater numbers in the southern part than in the northern. No particular localities in Kansas have been under observation. The notes on oviposition and nests were obtained in the Arbuckle mountains in Oklahoma.

HABITAT. The habitat, unlike that of *Tibicen aurifera* (Say), is in trees and usually along streams. Willows and cottonwoods are favored hosts. The adults are usually located by the songs of the males, but as they are often high in the trees they are much more difficult to take than the species thus far considered. The songs of the males are quite distinctive, having as a part of it a series of clicks more like the song of some of the Orthoptera.

OVIPOSITION. It is large broods of this species which oviposit in cotton and corn, in some localities causing considerable damage to the crops concerned. William Newell, U. S. Dept. of Agri., Bureau of Ento. 60, p. 52-58, gives an account of a brood in Ouachita valley, La., where twenty per cent of the cotton plants were destroyed. Some fields were so badly damaged that they were plowed up. One man reported more or less damage for the past twenty years, but that year (1905) was the worst. The corn was preferred to cotton, the insects choosing the part of the stalk just beneath the tassel and placing so many nests in them that the tassel died without functioning. He counted three stalks with 297, 181 and 215 nests respectively. Each nest contained from 4 to 5 eggs. It was his opinion that each female laid about 1,000 eggs, and would oviposit in almost anything, trees, shrubs, fence posts, roof and walls of sheds. Even the hoe handles became so roughened by the oviposition of this insect, if they were left exposed during the noon hour, that they had to be smoothed with sandpaper. He also records one nest in a hollow weed with 75 eggs in it.

A recent number of the Quarterly State Plant Board Plant Bul. of Miss., vol. 6, July, 1916, No. 2, carries the following paragraph on this species:

"A forty-acre field of cotton in Yunica county was severely injured by locusts or cicadas the latter part of June. The species responsible for the injury was *Tibicen vitripennis* (Say), which occurs throughout Mississippi, but is most abundant in the delta counties. The injury was caused by the females splitting the stalks and branches to deposit eggs, resulting in the death of the smaller stalks and the injured branches. About 90 per cent of the plants were injured and 25 per cent of the stand destroyed. Such heavy injury to cotton occurs very rarely. No control measures were used."

On July 17, 1925, nests of *Tibicen vitripennis* (Say) were collected in the cotton field of Mr. Sam Brown, four miles south of Davis, Okla., by the writer. The greater number of nests were found in the parts of the field nearest the timber which bordered the river. Only a small per cent of the stalks had been used as hosts, but in every case the placing of nests had resulted in the death of the plant above the nests. Usually the punctures had been made in the main part of the stem, although branches were sometimes used. Each nest was finished with a frothy excretion. The species had been heard singing in great numbers in practically every timbered section for miles around this locality.

NESTS. The nests were arranged in mismatched pairs, usually four or five pairs, only an ovipositor's length apart, then a little longer space before the next series began. In the stems sent to the laboratory there were from 13 to 37 nests in a stalk. The external appearance of the nest is not unlike that of *Melampsalta calliope* (Walk.). Perhaps they are a little less conspicuous from the fact that *Tibicen vitripennis* (Say) uses secretions in closing her nest. From three to seven eggs are placed in a nest, the number varying with the size of the stem used. They are 1.7 mm. long and 0.42 mm. wide, white in color when laid, turning to pink before hatching. *Tibicen vitripennis* (Say) occurs from June to August at least. No general statement as to the extreme times of egg laying or of hatching can be given. The eggs observed in the laboratory were laid before July 17. Red eyespots were observed in many of the eggs August 5 and hatching began August 7. These nymphs appeared to be hatching from one stem, while in other stems the eggs appeared very pink, and in still others the only pigmentation was the red eyespots. The hatch appeared to be complete August 15. The data are too meager to warrant conclusions, but if they are of any significance, would suggest a relatively short incubation period for the eggs. These stems were collected when only wilted and confined in a container for several days. When removed they were badly moulded, but the eggs were uninjured.

The newly hatched nymphs were placed in small glass cages in the open. September 20 two nymphs were found in a crab-grass cage, one still in the first stadium and the other in the act of molting. The first one was placed in a cage of orchard grass and was never seen again. The second one and its molted skin were preserved in alcohol. This specimen had a first stadium of six weeks. The total loss of this material was due, in part at least, to the experimental stage of rearing technique. No digging has been done for nymphs of *Tibicen vitripennis* (Say). An interesting question arises in connection with the nymphs hatching in cultivated fields. Do they all perish or are they, in nature, able to subsist on annuals?

Tibicen bifida (Davis).

ADULT. *Tibicen bifida* (Davis) is a brown and black cicada of medium size. A very striking character is the pruinose markings of the body, especially a dorso-median line extending the whole length of the insect. The opercula of the males are long and sharply pointed.

DISTRIBUTION. This species is confined to the western part of the state. The hills about Mr. Steele's ranch in Scott county fairly echoed with the songs

of the males in 1925. Semidesert, prairie hills, with very little vegetation except sage brush and scattered yucca plants, form the habitat. (Pl. XXVIII, Fig. 1.) It makes its presence known by the piercing song of the males and can easily be traced down and collected with a net. The species is active during the heat of the day, but early in the morning and late in the afternoon it becomes sluggish, and is more easily taken. Although the females were observed ovipositing, and photographs were made, they could not be carried about while at work as could specimens of *Melampsalta* and *Proarna*.

EMERGENCE. *Tibicen bifida* (Davis) is classed as an early species. It is out in June and gone by the last of July or the first of August.

OVIPOSITION. Adults of this species have not been confined for observation, and the individuals are so wary that detailed study could not be made in the field. Females have been observed ovipositing in dead yucca stalks, and hundreds of nests so placed have been taken. (Pl. XXXIV, Fig. 4.) They are often arranged in rows which tend to wind around the stem to avoid branches. They may, however, be placed at random on the stalk. The nests are closed with secretions. One female spent ten minutes filling and closing a single nest, using care to pat the torn tissues into place before leaving to make a new one. The nests are not conspicuous, yet may be found readily if the stalk is examined. Dead yucca fruiting stalks, preferably more than a year old, are commonly used. Very rarely a few nests are placed in a green stem. Four eggs are placed in a nest, usually the first one alone in the bottom of the nest, the next two crowded very closely together and overlapping each other and the two end eggs, the fourth extending nearly to the opening. They are white when laid, and about the same size as those of *Tibicen aurifera* (Say). After red eyespots appear the entire egg becomes pink. Eggs laid before June 18 showed red eyespots August 3, and August 7 some of the eggs were pink, while others were still white. August 10 cast postnatal skins were found about the nest opening of some stems which had been out of doors, but no nymphs were hatched in the laboratory until September 13. The hatch appeared to be complete by September 27. These data give a range of six weeks from the time of the first hatching to the last. The variation is probably due to differences in time of oviposition. The egg stage appears to be approximately three months. Eggs collected in August of 1926 were not brought into the laboratory until the 24th of this month, and no evidence of eggs having hatched was observed. In three days, September 3-5 inclusive, 445 nymphs emerged from a large handful of stems.

In the summer of 1925 some newly emerged nymphs were put into small glass-sided cages, and others were allowed to hatch naturally over large pots in the open. Sixteen nymphs were placed in a small cage of *Panicum virgatum* on September 17. The grass had been transplanted in June and apparently started growing nicely. One of these formed a cell against the glass with a new, white root running through it, and remained there clearly visible through the glass for many days. By October 1 its abdomen was much distended. Later the grass died, however, and when food ceased the nymph dug out of sight. When the cage was opened, October 26, only two live specimens were found. These were transferred to another cage and disappeared.

Interesting observations were made of another nymph. When first observed it appeared to be feeling the sides of the cell with its antennæ and front

claws. When it struck a root running through the cell, it clawed repeatedly, then appeared to insert its beak with difficulty. The middle and hind pairs of legs were raised to the back or sides of the cell, and the nymph gave every evidence of pushing. After inserting the beak, it remained very quiet for a considerable time feeding.

Others were placed in a cage of newly transplanted grass. When they were examined two or three weeks later they appeared no larger than when hatched. There was a marked difference in size between these and nymphs transplanted at the same time in cages of grass which had been growing. Nymphs appear to be unable to obtain nourishment from newly transplanted grass.

Of those which hatched over pots in the garden little is known. No conjecture can be made as to the probable number which emerged. An examination of the soil in these was made May 27 of the next year. The first pot examined contained wheat, yucca and *Panicum virgatum* as hosts. At this time the wheat had a nice root mass extending four to five inches in all directions, but at the time the nymphs entered the ground the roots must have been much fewer in number. The yucca had only a few large, short roots. There is no evidence that one of these would not have furnished food for a nymph if it had had the good fortune to find it, but the per cent which would find them would certainly be very low. The panicum showed only a few sprays above the surface, but had formed a mass of roots both large and small on one side extending to and covering the bottom of the pot. Just how much of this root mass was formed before the emergence of the nymphs it is impossible to say. The search for nymphs was made chiefly on the sides of the pot where wheat and yucca had been growing, although it extended some into the panicum roots. One nymph was found at the bottom of the pot on the grass roots. It was considerably enlarged, but had not molted. Further examination was not made because of the danger of destroying individuals which might be overlooked. This nymph was placed in a small glass-sided cage. June 4 one claw was found in a run that some tiny brown ants had made in the cage. Since the dirt was not all examined, and eggs were hatched over three large pots, it seems probable that data will yet be obtained from them. The information gained thus far indicates that at least some of the nymphs of *Tibicen bifida* (Davis) overwinter in the first stadium.

The nymphs hatched in September, 1926, were placed in a large cage of *Panicum virgatum* which had been growing since May, 1926. During the hatching period this cage was left lying on its side. The top glass was removed and the nymphs allowed to fall on the dirt above the roots. When opened and examined on February 3, 1927, one second-instar *Tibicen bifida* (Davis) was found with its cell constructed against the glass. It seems probable that the more rapid development in this cage than in the pot described above was due to the food supply, although differences in hatching time might also have influenced the development.

Considerable digging has been done in the field in the hope of finding nymphs. Excavations were made about and beneath yucca plants whose fruiting stalks showed old oviposition marks, but only a very few nymphs were found in all the trials. These have the typical wrinkled appearance of a *Tibicen* and can be told readily from the nymphs of the other two genera oc-

curring in this locality. An attempt was made to rear the material collected and it has either been lost through death of the individual or is still in the live cages.

Tibicen marginalis (Walk.).

ADULT. *Tibicen marginalis* (Walk.) is one of the largest of the Kansas cicadas. It measures from 36 to 39 mm. in length. In color the species is greenish and black or greenish yellow and black.

DISTRIBUTION AND HABITAT. This species occurs in the eastern third of the state. It is most commonly found in groves of willow or cottonwood along streams, although may be heard in other trees. A special study of this species has been made in a grove of birch on the farm of Mr. Wm. Payne, four miles northeast of Oswego, Kan., where large broods occurred in 1923 and 1926.

BEHAVIOR. The specimens are located by the continuous Z'we, Z'we, of the males. In the warmer parts of the day the adults are active and fairly difficult to take with a net unless the trees are low. The males are the most persistent and prolonged singers of any of the Kansas species. Their song begins as soon as the sun warms them in the morning and continues far into the night. Specimens have been heard as late as 1:30 o'clock in the morning. As the temperature is reduced with deepening night, the time of the song becomes slower. Just how long one male will sing continuously is not definitely known, but it is many times longer than for most of the other species.

EMERGENCE. Occasional specimens have been heard as early as June, and a lone male has usually sounded the last cicada note heard in the fall. In 1926 one was heard October 17. The largest numbers occur, however, in July and August.

MATING AND OVIPOSITION. Specimens have been observed in copula both in captivity and in nature. They remain either side by side or end to end. One pair mating in the top of a willow tree, perhaps twenty feet from the ground, was dislodged in an attempt to capture them. They fell striking the tree several times in their fall, but were not separated.

The female oviposits both in green and dead tissue and in a number of hosts. (Pl. XXXI, Fig. 7.) In Payne's pasture, in Cherokee county, birch is favored. Usually green twigs are chosen. These are often so cut by the ovipositor that they die. (Pl. XXXII, Fig. 1.) The corky bark of the trunks of willow is also used.

NESTS. The nests in green tissue are placed in one or two rows along the twigs, often slightly winding around the limb. If two rows are made the second nest is placed to one side and a little in advance of the first. Having filled the nest with eggs, the female forces the ovipositor deeply into the tissues just in front of the last egg thus raising the shreds up across the opening. She then exudes a secretion into the nest, which cements the improvised door in place.

EGGS. The eggs are pearly white, pointed at either end, 2.25 mm. in length and 0.5 mm. in width. The number of eggs in a nest varies from three to seventeen. The nature of the host used probably accounts, in part, at least, for the number of eggs placed in each nest.

Eggs collected in 1925 and kept suspended in the open until the following June showed red eyespots June 10, and hatching began June 15. A few nests

of these were laid in birch in Cherokee county and collected August 13; the rest were taken in Douglas county. These were in willow. The hatch appeared to be complete July 8. These data would give a period of at least ten and a half months for the egg stage and a little over three weeks for the hatching period.

PARASITES. The eggs of *Tibicen marginalis* (Walk.) are sometimes parasitized by a small braconid which Mr. S. A. Rohwer, of the United States National Museum, has identified as a new species belonging to the genus *Heterospilus*. There is but one parasite to a nest of eggs. At maturity the grub rests in the otherwise empty nest throughout the winter. As the season for the appearance of the next brood of cicades approaches, the larvæ pupate and in a few days emerge as tiny reddish-brown braconids.

NYMPHS. Of the nymphs hatched in the laboratory, 51 were transferred to a small cage of orchard grass, 58 to another small cage, and 186 to a large cage of *Sorghastrum nutans*. During a part of the hatching period the stems containing nests were placed over a large pot of willow and cottonwood trees in the open. The nymphs in the small cages had all disappeared when examination was made October 10. This loss has been considered to be due to ants and other predacious enemies. One limb of birch, particularly well filled with eggs, was placed over a cage in the open for a few days during the hatch. When examined again many small, brown ants were found crawling about the dead stem. They did not appear to have molested the eggs in the nests. As there was nothing else to attract them, they evidently were capturing the nymphs as they emerged. Although such a condition left unchanged would have been disastrous to the nymphs from this series of nests, such a circumstance doubtless is exceedingly rare in nature because of the habit of the females of placing them so far from the ground and scattered about in relatively small series. An examination of the soil in the large cage February 3, 1927, showed three nymphs, one of the second instar and two of the third with cells built against the glass. These were not disturbed, and extensive examination was not made because of the fear of overlooking and thus injuring the tiny nymphs. The sod in the cage was removed from the locality northwest of Midland where *Tibicen aurifera* (Say) is found and might have contained two nymphs of this species, which would account for the two third-instar nymphs near the glass. Otherwise they must be *Tibicen marginalis* (Walk.), which have molted twice since hatching in June. They were quite small for this instar.

Large amounts of soil were examined in the birch grove referred to in an attempt to find the nymphs, but none was obtained. This was thought to be due to the immense number of trees in the locality compared to the number of cicadas. Excavations near a large, solitary cottonwood tree in a pasture in Cherokee county where *Tibicen marginalis* (Walk.) predominated, yielded four fifth-instar nymphs of a *Tibicen* which was thought to be *marginalis* (Walk.). These nymphs occurred in cells from four to twelve inches beneath the surface. Three of these were pickled for study, and the fourth was transported 150 miles in a mud cell to the laboratory. When placed in a large cage of willow it formed a new cell and appeared to be unharmed by the experience. Examinations of this cage February 3, 1927, revealed the nymph apparently in good condition in a large burrow near the bottom of the cage.

Tibicen dealbata (Davis).

ADULT. *Tibicen dealbata* (Davis) was first described as a mountain variety of *Tibicen marginalis* (Walk.), then later was made a separate species. It differs from this species in having a shorter distance between the eyes and in having greater numbers of pruinose markings.

DISTRIBUTION AND HABITAT. This species is found over the western two-thirds of the state. It practically always occurs in the trees along the water-courses, willow and cottonwood being preferred.

BEHAVIOR. While *Tibicen dealbata* (Davis) occurs west of *Tibicen marginalis* (Walk.), and its emergence time is a little shorter (perhaps due to higher altitude), no difference has yet been detected in the behavior of the two. The song sounds identical, the habits of singing are the same, the nests of one might be mistaken for those of the other, the same types of hosts are used, and the time and method of hatching and the appearance of the eggs and nymphs are identical.

EMERGENCE. Near Mr. Steele's ranch in western Kansas a fairly large brood emerged late in June and was practically all gone by the middle of August. It is known, however, that some individuals of this species are out as late as the first of September. While the adults have been collected and their song has been recorded in many localities throughout western Kansas and eastern Colorado, only this one location has been found which combined accessible habitat and a brood of sufficient size to make study feasible.

Along the north side of the ford across Beaver creek two miles north of Mr. Steele's ranch, in the southern edge of Logan county, a large brood of *Tibicen dealbata* (Davis) was found in June, 1925. These were emerging from the sandy soil under a thicket of small cottonwoods and willow near the creek. Their emergence holes showed very plainly, smooth and fairly round. The edges were flush with the surrounding surface. On June 22, when they were first observed, they were not singing and appeared to have emerged recently. On June 26 the males were singing, but no eggs were found. This locality was visited again August 13. Only a few adults were left, but the trees, especially the cottonwoods, were spotted with small patches of brown leaves. These dead leaves were due to the stunting of the twigs by the oviposition of the females. Small green twigs about the diameter of a lead pencil were chosen. The female, standing with her head toward the tip of the limb, makes a nest of about eight eggs placed in two rows, then moves a little to one side and out and repeats the process. (Pl. XXXI, Fig. 6.) When the eggs have been deposited, she forces her ovipositor deeply into the tissue in front of the nest and cements the shreds across the nest opening exactly as described for *Tibicen marginalis* (Walk.). (Pl. XXXIV, Fig. 3.) So close are her nests and so ragged the openings that the outer tissues of a limb may be in shreds for six inches and around half of its circumference. This type of oviposition often weakens the twig until the wind breaks it off. Even where not broken the twig may be sufficiently stunted to cause the loss of leaves, and may even die. Usually where larger twigs are used the limb is scarred, but no further damage is done.

EGGS. The eggs are pearly white, 2.25 mm. in length and 0.5 mm. in width. They are deposited throughout the summer months and hatch the next June.

The eggs collected in August, 1925, were suspended in trees in the open. On June 8, 1926, no eyespots were visible, but on June 10, when they were placed in trays in the laboratory, an extensive examination of many nests revealed that some of the eggs in all the nests showed the eyespots, but not all of them did. June 13 nymphs began emerging. Some of these nymphs were placed in small cages; 312 were placed in a large, glass-sided cage of *Sorghastrum nutans*, and 287 were placed in a similar cage with willow as their host. All cages were buried in the open June 20. The nests were then suspended over a large pot of cottonwood in the open. An examination June 29 showed the hatch practically complete. Two nymphs emerged in a tray on that day. The above data gives an incubation period of at least ten months and a hatching period of sixteen days.

NYMPHS. An excellent opportunity to study the behavior of the nymphs was afforded by the small cages. One nymph was observed feeding a few hours after emerging. Unlike others observed, this one had its head bent back at a considerable angle, and the beak was still practically straight. This observation offered the suggestion that perhaps the beak at first is bent slowly, and even with some effort. When it is completely bent, however, it remains always so. No nymph has been observed, after the first day or two in the soil, which did not have its beak placed almost at a right angle to the body. The nymphs in the small cages appeared to thrive until placed in the open. When examined October 10, however, no trace was found of any of them.

The large cages were examined February 3, 1927. The willow trees had died leaving all the 287 nymphs to die. The grass, however, was in good condition. No nymphs were seen against the glass as were observed in the case of *Tibicen marginalis* (Walk.) and *Tibicen bifida* (Davis), and an extensive search was not made because of the danger of injuring those that might have survived.

Attempts to secure nymphs by digging in the Logan county locality were made on two occasions. Each time a few were found, but the series is still incomplete. In August, 1926, several nymphs were transported in mud cells by automobile to the laboratory. Two days' delay in transit necessitated the nymphs being so confined for three days. When removed, they all appeared dead. They were placed in an empty tray which was covered with a damp cloth and left over night. In the morning several of the nymphs were crawling about. Two fourth- and fifth-instar nymphs thus revived were transferred to artificial cells with roots running through them in a large cage containing willow. Six days later well formed cells could be seen where three of these had been placed. These were again examined Febraury 4, 1927, and found to be in good condition.

Tibicen dorsata (Say).

ADULTS. *Tibicen dorsata* (Say) is a large brown and black cicada with very conspicuous white pruinose spots. It is close to *Tibicen marginalis* (Walk.) and *Tibicen dealbata* (Davis) as to size, but may be separated from them by having the fore wings with cross veins between R_3 and R_{4+5} and between the latter and M_1, distinctly darkened.

DISTRIBUTION AND HABITAT. This is one of the commonest Kansas cicadas and occurs in all parts of the state. Unlike *Tibicen pruinosa* (Say), it does not prefer trees, and therefore is not so common about the cities and towns. It

is a lover of the wide open places, and, although it does not disdain to rest in a tree if there are trees about, it much prefers the open fields, even cultivated ones, and prairie land. It is very noticeable, in localities where this species occurs with *Tibicen dealbata* (Davis), that it is to be found out in the open perched on a briar, or even grass stems, perhaps not a foot above the ground, while *dealbata* will almost always be found in the larger trees of that locality.

BEHAVIOR. The adults are easily located by the songs of the males. During the heat of the day, especially at the first of the season, the species is wild. All the cunning of a wild-game hunter is required, and then one must be quick to strike and sure of aim to take them. This species, when it has been struck at with a net and missed, has the habit of flying up an angle of about 45 degrees and going usually out of sight. If perchance the specimen does not go out of range of the eye, it will appear to fall almost straight down when coming to earth and will alight immediately.

The song of the male is coarse and loud but not prolonged. As has already been stated, it sounds not unlike the distant hum of a mowing machine or certain type of tractor. Not a few females have been collected from the cab of a Fordson tractor while plowing. The females would fly about the engine and finally alight on it as it moved along. This species occurs so generally that it is difficult to find it plentiful enough to get much data. To render nymphs available by digging, a species must be localized in large numbers, and such a brood of *Tibicen dorsata* (Say) so far has not been found.

EMERGENCE. This species appears in June and is pretty well gone by September, although occasional specimens are found throughout this month. Perhaps the purest and one of the largest broods was studied in July, 1925, near St. Francis, Kan. Adults were out in large numbers July 3 in a large pasture covered with sagebrush. August 23 the adults were gone entirely. A bundle of stems of sagebrush bearing nests was collected at this time. Although the brood had disappeared so early in this locality in the extreme western part of the state, specimens were observed in eastern Kansas the same year until September 10, and in 1926 they were kept alive in outdoor cages until September 30.

FEEDING. When furnished with the proper food this species will live, apparently happy, for several weeks in captivity, whereas, if confined without food the specimens die in a short time. Adults begin to feed within a few seconds after being placed in a live cage, and have been observed to feed frequently throughout confinement.

MATING. Matings were observed both in captivity and in the field. It is as has been described in other species. They may be end to end or side by side. Probably the latter is the normal way, and it is only by being disturbed that they change.

OVIPOSITION. (Pl. XXXI, Fig. 5.) The female oviposits in anything that is at hand. Green tissue or dead is used without preference. Nests collected near St. Francis, Kan., from sage brush were mostly placed in dead stems. Large numbers of nests were also made in captivity. Perhaps most of these were in green tissue, although dead twigs were provided so the females could have their choice. The nests in green material resembles those of *Tibicen marginalis* (Walk.) as to arrangement and appearance. In dead material they may be scattered about or in single rows. This is governed somewhat by the

size of the material used. If it is a large stem the nests may be scattered, while if it is a small twig they are usually in a single row.

The number of eggs in each nest varies according to the kind of material in which the nests are placed. In soft material, either dead or green, the number varies from twelve to fifteen to the nest, while in hard wood the number varies from three to five, with a preference for three. After the last egg is laid the female cuts a few shreds of material from the limb by inserting the ovipositor at the end of the last egg, and cements them in place, thus very effectually closing the nest. This is done in either dead or green tissue.

Eggs. The eggs are spindle shaped, a little more pointed at one end than at the other. These, as other cicada eggs, are often distorted in shape to conform to the chamber in which they are placed. They measure 2.75 mm. in length and 0.5 mm. in width, and are pearly white in color.

The eggs collected in August, 1925, were suspended in the open until June, 1926. June 10, red eyespots appeared, and June 12 an examination revealed some empty shells. June 13 the first nymphs emerged in the laboratory. The hatch appeared to be complete by June 29. This indicates that *Tibicen dorsata* (Say) has an egg stage of about ten months and a hatching period of a little over two weeks.

Fifty-two of the newly emerged nymphs were placed in small glass cages and seventy-seven were transferred to a large cage of *Sorghastrum nutans*. As with the other small cages of newly emerged nymphs, so *Tibicen dorsata* (Say) nymphs disappeared completely in a few weeks after having been placed in the open. The large cages were examined superficially February 3, 1927. The grass was in good condition. No nymphs were observed, but extensive search was not made through the soil.

Extensive excavations in the sagebrush locality failed to reveal a single nymph. Cast skins could be found on the ground about the bushes, and old ovipositor marks were located, but the nymphs were apparently so evenly distributed over so large a territory that they could not be located with a reasonable amount of work. The sandy nature of the soil would render the tiny nymphs almost indistinguishable, thus adding to the difficulty of finding them.

Better success was enjoyed in a sumac thicket in a pasture on Mr. Al Smith's place, three miles west of Lawrence, Kan. *Tibicen dorsata* (Say) adults had been taken there in sufficient numbers to suggest the possibility of finding the nymphs. Excavations near old shrubs yielded a fair number of individuals on the first attempt. Occurring with these, however, were nymphs of *Tibicen aurifera* (Say). The fifth-instar nymphs could readily be distinguished, but the smaller ones required more study. Some of these nymphs were preserved for laboratory work, and others were transplanted in small glass cages. When a second attempt was made to collect material it was discovered that sheep had eaten the sumacs and other shrubs so completely that it was impossible to recognize where the first digging had been done. This attempt yielded very little material. Thus, while it has been demonstrated that the nymphs feed on perennial roots in cells from three inches to twelve inches beneath the surface, and that they will live on grass roots in small cages, no data have been obtained on the probable length of the life cycle. The series

of nymphs is not complete. They do add their bit of proof to the supposition that the nymphs of the different species within a genus are confusingly alike. This is not surprising when one considers that many of the adults are classified by size and color, characteristics which are not satisfactory with the nymphs.

Tibicen pruinosa (Say).

ADULT. While *Tibicen pruinosa* (Say) is perhaps the best known cicada in Kansas, little information has yet been gathered on its life history. It occurs every year through several months in almost every grove in the state. Especially does it predominate in cities and towns. Even in a locality where other species, such as *Cicada hieroglyhica* Say or *Tibicen marginalis* (Walk.), have been found in large broods in the woods surrounding the towns, the lazy "Za-wie, Za-wie" of *Tibicen pruinosa* (Say) is the song that lulls the inhabitants of the city to peaceful reverie or irritates them to murderous thoughts, according to the particular disposition of the listener. The nearest approach to a brood of this species which has yet been observed was found in September, 1926, in an apple orchard near Waverly, Kan. No opportunity was offered, however, for an extensive study of this brood. Adults have been collected in Cherokee county and in Douglas county and their behavior studied in live cages. (Pl. XXXIV, Fig. 5.)

HABITAT. As has been suggested, it is essentially a tree-loving species, and the adults are located by the singing of the males. Live specimens are collected by means of the long-handled net referred to previously. The females are located by scanning the surfaces of the limbs and trunks of the trees. They are so nearly the color of the host that some practice is necessary to enable one to see a very large per cent of those actually present. If the trees are small and the grove not too dense, specimens which escape may often be followed to their new position. In groves of large trees they have a disheartening tendency to fly to a higher perch when disturbed.

EMERGENCE. The largest numbers emerge at night, although it is not uncommon to find nymphs crawling about in the daytime in search of a desirable spot for transformation, or to find specimens in some stage of this process during the day. Often one is found which has been fatally injured but is still alive and soft, showing that its emergence had been started in the daytime.

On August 29, 1926, about a quart of cast skins were collected near the sidewalk along a half dozen city blocks with the idea of obtaining any information these might offer. Some of them were on the ground at the base of the trees, others were on grass blades or weeds near the base, a much larger number, however, had found the trunks of the trees and crawled up. Skins could be seen 20 feet from the ground. No data have been obtained as to how high some had gone.

At 5 p.m. a nymph was found about five feet from the ground, crawling slowly up the trunk of an elm tree. It was removed to the arm of the collector where it continued its crawling while the observer walked two blocks. It crawled in an upward direction. At the laboratory it was removed to an elm limb an inch and a half in diameter and two and a half feet long. When moved from one place to another with the hands it immediately resumed its climbing upon being released. When it reached the top of the limb the limb

was inverted, and it turned around and began ascending it immediately. About halfway to the top it stopped and carefully lifted and placed each pair of legs on the bark. No estimate could be made as to how far the emergence hole was from the base of the tree where it was found, but it was estimated that the nymph had crawled about twelve feet after reaching it, and had spent over one-half hour doing so. Having placed its legs satisfactorily, the claws of the middle pair firmly imbedded in the bark, the nymph rubbed its face and antennæ repeatedly with its front claws. Then it stood quite still for a moment and again rubbed the front legs carefully over the head. It finally came to rest with the front claws suspended in the air. At 5:50 the skin burst slowly in a dorso-median line the length of the mesothorax. In three minutes the slit extended to the frontal suture, whence it quickly opened crosswise to the antennæ, at the same time extending backward to the first abdominal segment. During this splitting of the skin no motion could be detected, but upon its completion a rolling motion within the body began. By 5:55 the body was bulging visibly through the opening. Four minutes later slight quivers were noticed in the mesothorax every few seconds. By 6 the head had slipped clear of the skin and the quiverings were more frequent. At 6:02 the first segment of the front legs was clear of the skin and the crumpled wings were emerging. At 6:05 the second joint of the front legs had appeared and only the tips of the wings were holding in the skin. The wings were very light green, orange and white mottled. At 6:08 the wings were free and the legs practically so. At 6:09 the wings were held horizontal to the body. The body was extended at right angles to the shell, ventral side up. The body quivered again two or three times. At 6:11 it folded its tarsi a little. By 6:13 the abdomen was still holding but the feet were all free, and the mouth parts, which had been separated, all came together again in a normal position. At 6:14 the wings were expanding slightly; the hairs on the tibia had become black; the tarsi were orange and the remaining portions of the legs green. At 6:18 the wings appeared mostly light green, the body bent down from the horizontal at about a 60-degree angle. At 6:23 the hind pair of legs moved a little and came to rest at right angles to the body. At 6:28 it raised the body up, caught hold of the exuvium with all legs, and began to move the wings, which were enlarging rapidly. At 6:29 the abdomen was freed from the now empty shell. The genitalia (male) were protruding out and back. The wings were nearly one inch long, with the veins green. At 6:33 the left wing was enlarged noticeably more than the right. This was thought to be due possibly to the current of air on the left side caused by the explosion of flash-light powder. The wings were milkly to clear. At 6:38 it moved to the left side of the shell and off on to the limb. The wings were nearly full length, the genitalia still protruding. At 6:42 it moved the legs a little; at 6:48 the wings were much clearer but still held flat, the veins light green. At 8:50 the cicada had crawled to the top of the limb. The wings were held rooflike, the color markings pale, the body soft, the genitalia not entirely retracted. The following morning the cicada appeared a normal, mature male. He was placed in a live cage where he was later observed singing and feeding.

The above is the only emergence which has been observed in such detail and timed as closely, but it is considered to be essentially characteristic of the various species. In all cases it appears to be the claws of the middle pairs of legs

which hold the cicada while emergence if effected. The front pair of legs are left free to assist in freeing the loosening skin from the delicate structure of the anterior part of the body.

Tibicen pruinosa (Say), like those already described, feeds on any convenient host at all hours of the day.

Numerous matings were observed in captivity. The process requires from a few minutes to one and a half hours. More than one male may mate with the same female. It was interesting to note that the variety *fulva* Beamer, which has been found in Cherokee county only, intermates with *Tibicen pruinosa* (Say) without discrimination. Dark males with light females, dark females with light males, light males and females, and dark males and females have all been observed mating in the same cage. Other males in a cage become greatly excited and sing lustily when a pair is in copula.

OVIPOSITION. In most of the cases of oviposition which have been observed in the field the female was using the corky bark of the trunks or the large limbs of live trees. In cages where the live host is small green twigs oviposition has always been in dead limbs placed in the cage for that purpose. No nests have been found in small green limbs. They are placed at random. The external appearance is similar to the hole made by inserting a pin into the bark. Observations would tend to show a preference of the females in nature for relatively low positions on the trunks of large trees. Very often nests are placed no higher than on a level with one's eyes. The females can often be observed at short range in the field, although they are more wary than some of the smaller species.

Tibicen auletes (Germar).

ADULT. *Tibicen auletes* (Germar) is the largest species of cicada known to occur in Kansas. It measures 40-42 mm. in length. In color it is greenish brown and black. Newly emerged specimens are almost entirely covered with pruinosity.

DISTRIBUTION AND HABITAT. This species occurs practically all over eastern Kansas. It is, as a rule, not an abundant species. A male may be heard singing almost any day, but very rarely does one hear many. A rocky draw running east from Lyons creek just east of Woodbine, Kan., is the only locality where a brood has been located. There, in 1923, a large brood of this species was found. This locality has been visited each year since in the hope of obtaining data on the length of the life history of this species. In 1924 there appeared to be almost as many specimens out as in 1923, but none were found in 1925, and only an occasional one in 1926.

Tibicen auletes (Germar) is easily detected by the song of the male which, at least in this region, is loud and harsh. The song begins slowly, gradually increasing to a crescendo and then subsides. It is represented by the following: T - T - T - T-T-T-d-d-d-d-d-d-d-T-T-T. The T is repeated slowly and the d quite rapidly with a crescendo in the middle. The noise is fairly deafening during the hours when a large brood sings. Greater numbers sing from 9 to 11 a. m. and from 2 to 5 p. m.

Rocky ravines and hillsides covered with oak trees, *Quercus stellata*, etc., are preferred habitats. The adults are not unusually wild, and if the trees are short the specimens may be taken easily with a net.

OVIPOSITION. The females, in all cases observed, were ovipositing in the dead limbs of the oak trees which they frequent. The limbs used were about three-quarters of an inch in diameter and had been dead for some time. The nests are not placed in any regular manner. They were usually on the under surface of the twig and very hard to locate if the female was not present, as the opening appears about as any other abrasion of dead bark. Oviposition occurs in August and September.

No rearings have been attempted on this species. Material has been too scarce the past two years to secure eggs and thus begin rearings, and the habitat in which this species delights is so rocky that digging for nymphs in the field is practically impossible.

Tibicen chloromera (Walk.).

ADULT. *Tibicen chloromera* (Walk.) is a medium-sized cicada, almost black in color. It may be separated from *Tibicen lyricen* (DeGeer), which it closely resembles, by its very long opercula and by the white color of the venter.

DISTRIBUTION AND HABITAT. This species is confined to the southeastern portion of the state, having been collected in various parts of Cherokee county, but studied in detail only in a birch thicket about four miles northwest of Hallowell, on the farm of Mr. Wm. Payne. Here a large brood was observed in 1923, and many specimens were taken. Comparatively few individuals occurred in 1924 and 1925, but in the summer of 1926 another large brood occurred. This locality was visited August 26, and again the second week in September. In the early morning the woods rang with their song, but by 10 o'clock it had subsided, and throughout the remainder of the day only an occasional individual was heard. One might have spent considerable time in the woods in the afternoon without being aware of the presence of this species, although males of *Tibicen marginalis* (Walk.) and *Tibicen pruinosa* (Say) sang in great numbers throughout the day.

A few specimens of this species have been heard singing in July, but the greatest numbers occur from the latter part of August till the middle of September. Males confined in cages sing, but not as frequently and persistently as those of the other species studied at the same time.

FEEDING. Adults have been observed feeding on birch, maple and apple, all hosts on which specimens have been caged. They feed freely and often as do the other species.

MATING. Matings were observed frequently in captivity. A pair remained in copula for from one-half hour to over an hour. Several specimens were confined for several hours in a large pasteboard box with specimens of other species during their transportation from Cherokee county to Lawrence, Kan. When they were removed to live cages after the trip, a female *Tibicen chloromera* (Walk.) was found in copula with a male *Tibicen pruinosa* (Say).

OVIPOSITION. One female was observed in the open making a nest in a green birch limb less than one-half inch in diameter. She made one nest and sealed it carefully with a secretion, then began another nest, when a careless motion frightened her away. She allowed the observers to bend the limb on which she was working several feet nearer the ground and to watch her at a distance of perhaps four feet for several minutes. Another female observed in nature

was ovipositing in dead willow. She, too, was relatively gentle, allowing the observers to approach to within a few feet of her. Several pairs were confined in live cages over birch, maple and apple. In cages the females used dead tissue exclusively for nidification. In all cases the nests were closed with secretion.

The nests are placed irregularly. From the meager data obtained one would infer that the females do not lay as many eggs as in many other species; or at least, if they do, that they scatter their nests far apart and oviposit over relatively long periods of time. Very little external evidence is left when the nest is completed. The external opening is entirely filled with a gluelike substance appearing externally much as a bit of the gum which exudes from a wound in a cherry or peach tree. Specimens of this species confined the same length of time as other species laid far fewer nests.

From nine to eleven eggs are placed in a nest. They are arranged in two rows similar to those of *Tibicen aurifera* (Say), etc. (Pl. XXXI, Fig. 3.) The nests are very close to the surface of the twig, and the last egg in a great many cases extends almost flush with the bark. (Pl. XXXVIII, Fig. 5.)

The eggs are 2.33 mm. in length and about 0.5 mm. in width. They are white and of the same general shape as other cicada eggs. None have been hatched in the laboratory.

Tibicen lyricen (DeGeer).

ADULT. *Tibicen lyricen* (DeGeer) is a medium-sized cicada, black in general color with some brown markings. It resembles very closely *Tibicen chloromera* (Walk.), from which it may be easily recognized by the smaller and more sharply pointed opercula.

DISTRIBUTION. This species seems to be fairly well distributed over the eastern half of the state. Only occasionally does it occur in fairly large broods in any one locality. It is usually represented by a few specimens in almost all woodland.

HABITAT AND BEHAVIOR. This species is fond of trees, the larger the better. It is only where the forests are low that one may take the species easily with a net. The adults are readily located by the songs of the males. These are of short duration and characteristic of the species. They resemble somewhat those of *Tibicen chloromera* (Walk.) but do not have the crescendo of the latter species.

EMERGENCE. *Tibicen lyricen* (DeGeer) has been collected from July 13 to September 18. The greatest numbers occur in August. One locality about five miles south of Garnett, Kan., where a large brood of this species appeared in 1923, has been under observation each year since. This place is a north slope too poor to support but a very meager vegetation. Persimmon trees growing there are not much over the height of an ordinary man, and other vegetation in proportion. This made an ideal location to observe the adults, and it was here that the females were observed in oviposition. Small dead persimmon twigs were chosen, smaller than a lead pencil. When the nest was completed the opening was filled with secretion and the torn shreds of the host so well replaced that it was next to impossible to find the nest after the female had gone.

OVIPOSITION AND NESTS. The nests occur singly scattered over the twigs. They may be placed either in dead or live tissue. As was published in Annals of Ent. Soc. of Am., Vol. XVIII, pp. 479-482, the nests differ from other species in that one, two or three nests may be made from one external opening. The nests may all be in the same general plane, radiating from a common center, or one may be below the others.

EGGS. There are from six to twelve eggs in a nest, placed in the regular order and of about the regular size. No data have been secured recently on this species, as it has not appeared in large numbers the past two seasons, and attempts to dig for nymphs have resulted in failure.

Tibicen linnei (S. & G.).

ADULTS. *Tibicen linnei* (S. & G.) resembles *Tibicen pruinosa* (Say) very closely in general appearance, but the songs are markedly different. The former is reputed to have a bend in the costal margin of the front wing, while the latter has the costal margin an even curve. In reality specimens collected and confined in live cages have shown the inaccuracy of separating them by these characters alone. After a careful study of many specimens of both these species the shape of the posterior end of the opercula seems the only infallible character. (Pl. XXX, Figs. 4, 5.) This is a character which is easily seen, and proved constant for a great many specimens which had been killed while singing.

DISTRIBUTION AND HABITAT. This species occurs only in the northeastern third of state. It lives in trees, the same as *Tibicen pruinosa* (Say), and in this section is to be found closely associated with it.

BEHAVIOR. The males are located by the song. This sounds much as a few bits of glass would if rattled in a tin box. The males have been observed to crawl nervously about during the song, either backward or forward but not going far in either direction.

EMERGENCE. No large broods have been observed. During the fall of 1926 many hours were spent collecting live adults of both *Tibicen linnei* and *pruinosa,* for it was impossible to tell them apart even after they were taken. At this time a study of the distinguishing characters had not been made. Attempts to separate the two species by the curve of the wing resulted in failure. Several specimens were isolated by this character for *Tibicen linnei* (S. & G.) only to have the males, in practically every case, sing out in the approved song of *Tibicen pruinosa* (Say). Specimens of *Tibicen linnei* were obtained, but in no case where oviposition was obtained of isolated specimens did this individual prove to be the desired one. Hope was held that if males could be located by their song and placed in live cages with females of the two species their mating would identify the females. However, since individuals of different species have been known to mate, this does not offer an infallible proof. While *Tibicen linnei* was heard singing almost daily for several weeks during the summer and fall of 1926, it did not occur in sufficient numbers to make extensive study easy. Almost invariably the males which were singing could be traced to a perch high above the reach of the longest net, and attempts to climb for them resulted in frightening away the cicada, which flew high and far out of sight.

Magicicada septendecim (Linn.).

Magicicada septendecim (Linn.) is not mentioned here with the hope or thought of adding anything new to its life history. It being the one species whose life history has been recorded, has been used as a control. A brood has not emerged in Kansas since the present work was started, and hence no comparison from first-hand data can be made on the adult behavior, the egg, or first nymphal stages of the species with the others studied.

A locality covered with locust trees was found west and south of Lawrence on the Wakarusa river where Dr. H. B. Hungerford had collected this species in quantities in 1911. Digging in this locality yielded nymphs in unsuspected numbers and gave an excellent opportunity for the study of nymphal behavior in nature, and also gave abundant material for laboratory experiments. It is to be regretted that this rich field was not located sooner, so that the first experiments with cages and hosts might have been conducted with them. With such experimentation much of the valuable material which was lost might have been saved.

Only two broods of this species are recorded for Kansas each seventeen years. These belong to Marlatt's broods Nos. 1 and 4. Brood No. 1 will emerge in 1928, and brood No. 4 in 1930. Both broods were represented in the material dug in this locality. Individuals of brood No. 1 were in the fifth stadium and were perhaps ten times as numerous as those of brood No. 4, which were in the fourth stadium. Considerable difference was noted in the size of the individuals within the stadium. Some appeared just to have molted, others appeared to be mature. How much variation there may be in nymphs which will emerge the same season cannot be given at this time. Considering the probable presence of the variety *cassinii* (Fish.) with the seventeen-year, one would expect considerable difference in the nymphs. However, some observations have been made which show there are different aged specimens present.

Early in the spring of 1926 many nymphs were preserved and several of both instars were placed in live cages. In June an adult was heard singing in the trees near the laboratory, and a careful study was made of the locality where digging had been done. Occasional emergence holes were observed; a dozen skins could have been collected without difficulty; a male specimen of *cassinii* (Fish.) was taken alive, still soft, and an occasional male could be heard in the trees. There were too few, however, to obtain much data on them. The male taken alive lived for two weeks and sang daily in a cage over cherry. A number of other specimens were taken in various localities scattered over southeastern Kansas this same spring, and numerous others were heard singing. Of the nymphs in live cages a large per cent of them lived, feeding on grass roots, even though the cage was little thicker than the cell. Two of the fourth-instar nymphs molted into fifth in captivity while the others remained in the fourth stadium, showing again that all would not emerge the same year.

CONCLUSIONS.

From the data recorded in the preceding pages, it seems logical to conclude:

1. Adult cicadas may be transported long distances and kept in live cages for as long as three weeks, singing, mating and ovipositing normally.

2. Adults feed frequently by sucking juices from living plants. Neither nymphs nor adults are specific feeders.

3. Females of most species will oviposit in a wide variety of hosts, but show a preference for certain types of material. The number of eggs placed in each nest varies with the species and with the type of material.

4. Females of most species exude a gluelike secretion into the nest before leaving it, and when this is done their eggs are not affected by the withering of the host.

5. Eggs of different genera and species vary in appearance when laid only as to size. During maturation the eggs of some turn pink while those of others remain white, the pink color persisting through the first-instar nymphs only.

6. The eggs of all the genera except *Tibicen* hatch the same season they are laid. All the species of *Tibicen* except two overwinter the first year in the egg stage—*Tibicen bifida* (Davis) and *Tibicen vitripennis* (Say).

7. Temperature and moisture influence the time and rate of hatching of the eggs.

8. For practical purposes the nymphs require soil to thrive.

9. Nymphs feed throughout the greater part of the year, at least and cannot subsist on annuals.

10. Nymphs may be taken from the field, transported long distances in artificial cells and placed in cages, where they continue development.

11. Nymphs remain in the same cell if the food is satisfactory but will burrow extensively if the host dies.

12. There are five instars, with no evidence of a pupal or resting stage before emergence.

13. The number of segments of the tarsi change from two to one and back to two again during nymphal life. The number of setæ-bearing spines on the apex of the tibiæ also change.

14. Emergence is predicted by deepening of body color in many cases, and always by darkening of eyes from white to red or black.

15. The complete life cycle may be run in captivity.

16. All Kansas cicadas have a life history covering several years. That of *Melampsalta calliope* (Walk.), the smallest of our Kansas cicadas, is completed in approximately four years.

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EXPLANATION OF PLATES.

(231)

PLATE XXVIII.

FIG. 1. A typical habitat of *Tibicen bifida* (Davis) in Scott county, Kansas.

FIG. 2. A meadow habitat of *Melampsalta calliope* (Walk.) eleven miles west of Lawrence, Kansas.

PLATE XXVIII.

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PLATE XXIX.

FIG. 1. A typical view in the Beaver Creek valley, Scott county, Kansas The grassy plot in the foreground is the location from which the hundreds of *Melampsalta calliope* (Walk.) nymphs were taken. The persons in the foreground were observing the oviposition of this cicada at the time the picture was taken.

FIG. 2. Digging for *Melampsalta calliope* (Walk.) nymphs in Scott county Kansas. Breaking up the sod over a dirt table.

PLATE XXIX.

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PLATE XXX.

FIG. 1. *Melampsalta calliope* (Walk.) ovipositing in sweet clover.

FIG. 2. *Tibicen marginalis* (Walk.) ovipositing in dead willow.

FIG. 3. *Tibicen aurifera* (Say) ovipositing in *Panicum virgatum* near Midland, Kan., September 22, 1923.

FIG. 4. Venter of *Tibicen pruinosa* (Say), showing the more rounded opercula.

FIG. 5. Venter of *Tibicen linnei* (S. & G.), showing the pointed opercula.

PLATE XXX.

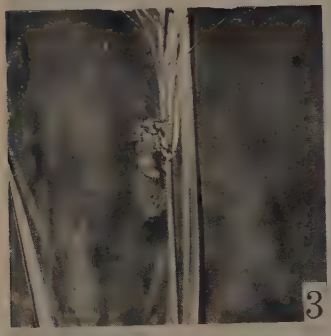


PLATE XXXI.

FIG. 1. Enlargement of a stem of *Panicum virgatum,* showing the external opening of three nests of *Tibicen aurifera* (Say). The tissue of the plant is very carefully patted back into place by the outer valves of the ovipositor after a sticky secretion has been placed on it.

FIG. 2. Grub of a small green hymenopteron belonging to the genus *Syntomaspis,* in place in the nest of *Tibicen aurifera* (Say). Same magnification as the eggs in Fig. 3.

FIG. 3. Nest of eggs in a stem of *Panicum virgatum* made by *Tibicen aurifera* (Say). This shows the typical arrangement of the eggs in the nests of most of the species studied.

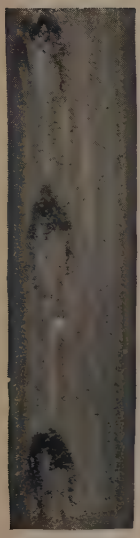
FIG. 4. Rows of nests of *Tibicen aurifera* (Say) in stems of *Panicum virgatum.* Note the even arrangement.

FIG. 5. Nests of *Tibicen dorsata* (Say) in sagebrush.

FIG. 6. Nests of *Tibicen dealbata* (Davis) in cottonwood, showing how the young limbs are macerated by the ovipositor.

FIG. 7. Nests of *Tibicen marginalis* (Walk.) in birch. The smaller twigs are often killed by oviposition.

PLATE XXXI.



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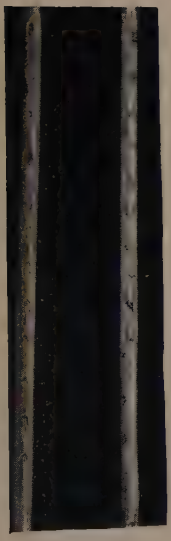

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PLATE XXXII.

FIG. 1. Scars on birch limbs one year after oviposition by *Tibicen marginalis* (Walk.).

FIG. 2. Nests of *Melampsalta calliope* (Walk.) in sweet clover. Some idea of the number and arrangement is shown. Very often not a single branch of the entire plant escapes.

PLATE XXXII.

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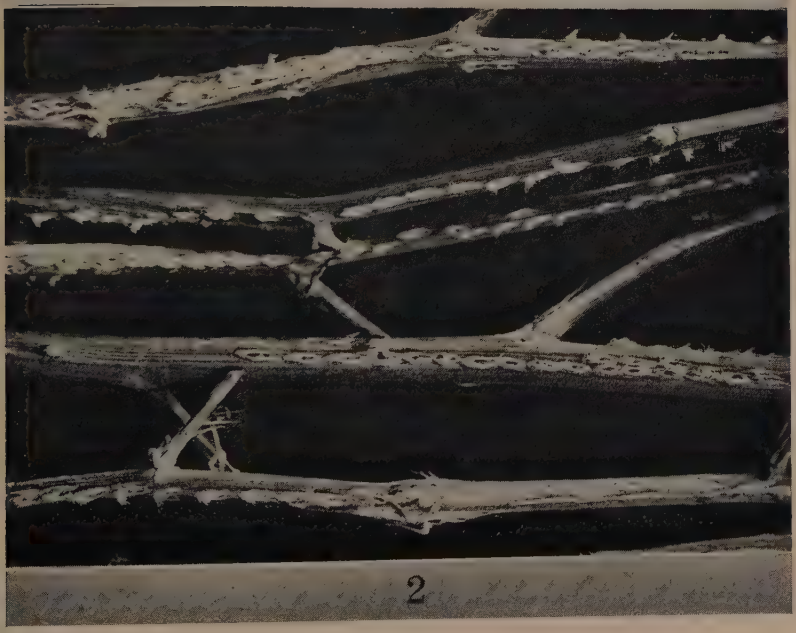

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PLATE XXXIII.

FIG. 1. A cage using 8 by 10 glass, containing nymphs of the seventeen-year cicadas. One of the nymphs dug through the base of the cage in the left-hand corner.

FIG. 2. Bottom of the cage shown in Fig. 1, with the exit hole of the *Magicicada septendecim* (Linn.), fifth-instar nymph.

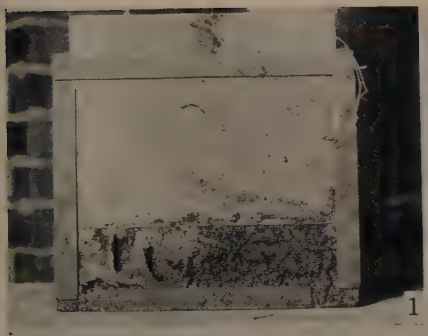
FIG. 3. A large pot of *Panicum virgatum,* showing the extensive root mass.

FIG. 4. Lump of dirt broken open, showing a fifth-instar nymph, seventeen-year cicada's cell and nymph.

FIG. 5. A large potato containing four fifth-instar seventeen-year cicada nymphs in artificial cells. The cells are closed with small squares of celluloid inserted in slits in the potato.

FIG. 6. A small glass-sided cage containing orchard grass from which a *Melampsalta calliope* (Walk.) nymph has just emerged. Part of the tunnel is shown as well as the exuvium just to the right of the plant.

PLATE XXXIII.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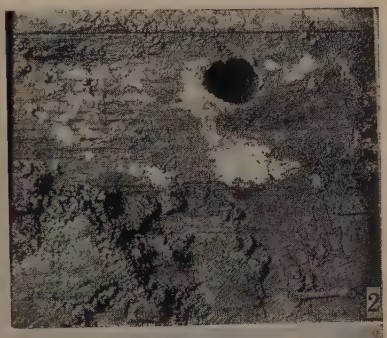
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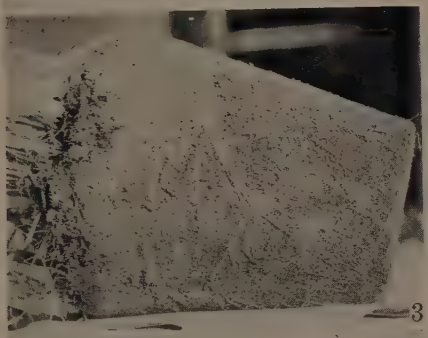
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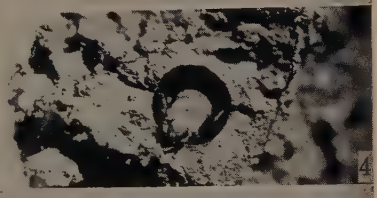
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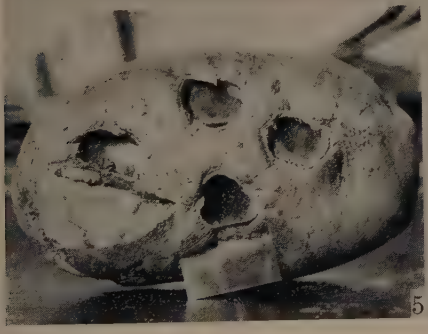
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PLATE XXXIV.

FIG. 1. *Tibicen aurifera* (Say) mating on a compass plant near Garnett, Kan., September 7, 1926.

FIG. 2. A close view of some of the hard, stubby limbs of the oak, *Quercus marilandica,* in which *Cicada hieroglyphica* Say delights to make her nests.

FIG. 3. Nest of *Tibicen dealbata* (Davis) in cottonwood, side view, showing three eggs and the torn tissue at (*a*) which is pushed up to close the nest. This is accomplished by an additional insertion of the ovipositor. The material is held in place by a secretion.

FIG. 4. *Tibicen bifida* (Davis) ovipositing in the flower stalk of a yucca plant in Scott county, Kansas.

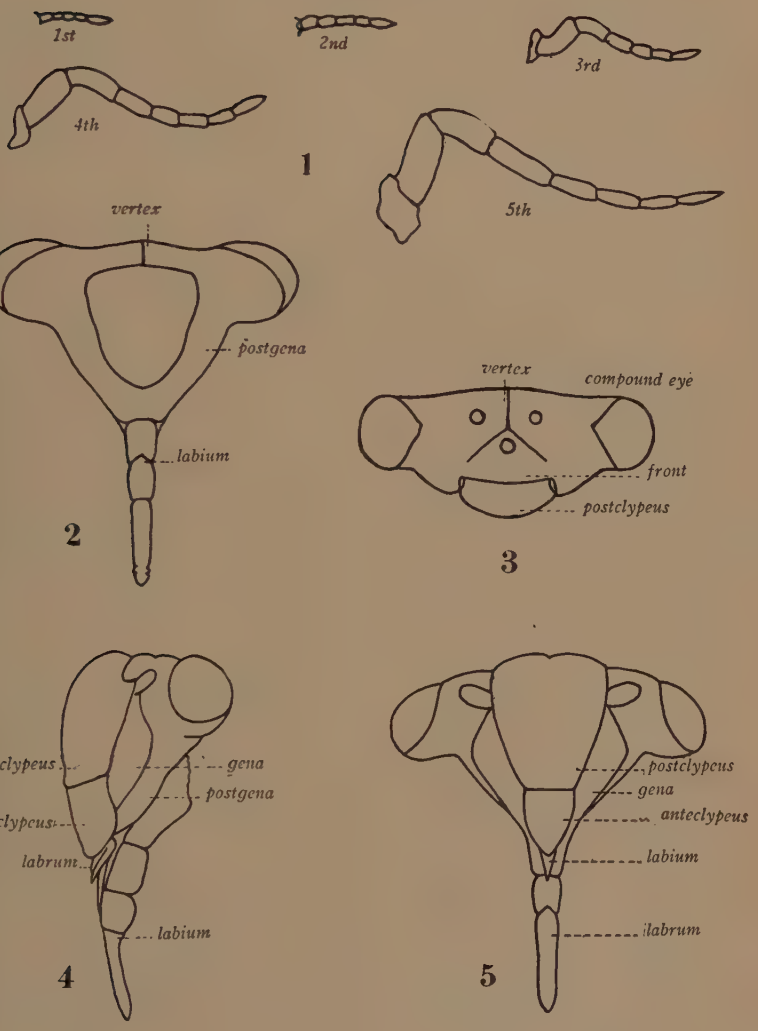
FIG. 5. Live cage on elm for *Tibicen pruinosa* (Say). The adults live, apparently content, in this type of cage. The mosquito netting from which they are made does not injure the specimens when they fly against it.

PLATE XXXIV.

PLATE XXXV.

FIG. 1. Right antennæ of various instars of *Melampsalta calliope* (Walk.).
FIG. 2. Caudal aspect of the head of *Melampsalta calliope* (Walk.).
FIG. 3. Dorsal aspect of the head of *Melampsalta calliope* (Walk.).
FIG. 4. Lateral aspect of the head of *Melampsalta calliope* (Walk.).
FIG. 5. Cephalic aspect of the head of *Melampsalta calliope* (Walk.).

PLATE XXXV.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2nd
3rd
4th
1
5th
vertex
postgena
labium
2
vertex
compound eye
front
postclypeus
3
postclypeus
gena
postgena
anteclypeus
labrum
labium
4
postclypeus
gena
anteclypeus
labium
labrum
5

PLATE XXXVI.

Morphology of the adult of *Melampsalta calliope* (Walk.).

FIG. 1. Cephalic view of prothorax.

FIG. 2. Lateral view of prothorax.

FIG. 3. Dorsal aspect of prothorax.

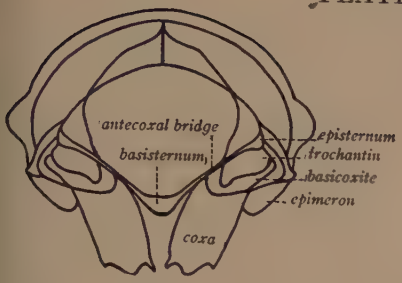
FIG. 4. Ventral view of thorax.

FIG. 5. Dorsal aspect of meso- and metathorax.

FIG. 6. Ventral view of the abdomen of ♀ (female). *Is*, first abdominal sternite; *IIs*, second abdominal sternite, etc.

FIG. 7. Ventral aspect of abdomen of male. *Ist*, first abdominal sternite; *VIIIs*, eighth abdominal sternite.

PLATE XXXVI.



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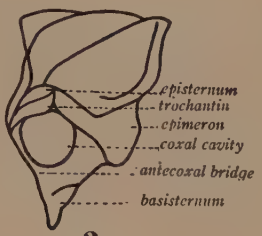

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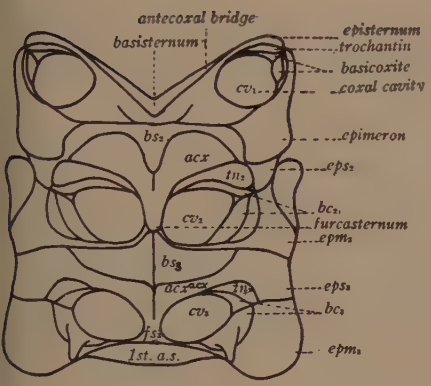

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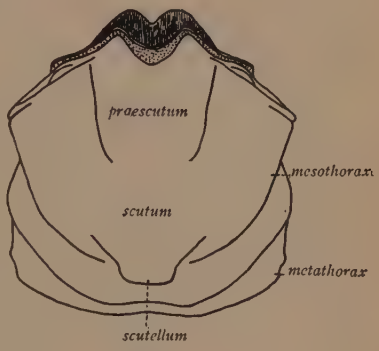

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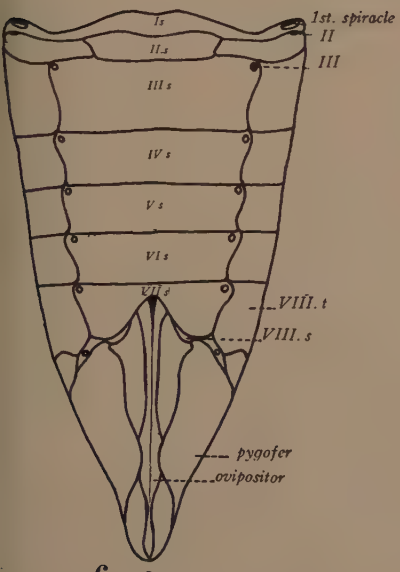
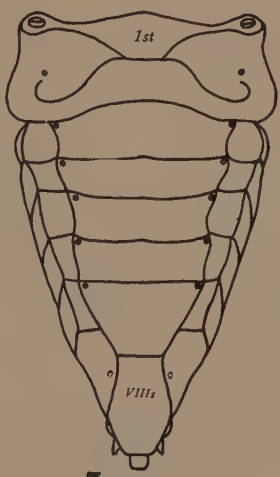


6 ♀



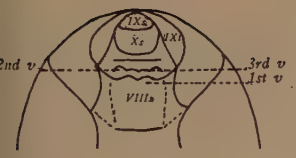
7 ♂

PLATE XXXVII.

Melampsalta calliope (Walk.).

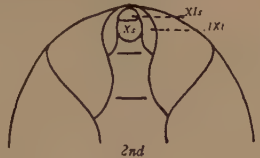
FIG. 1. Tip of abdomen of first instar. *XIs,* eleventh sternite, etc.
FIG. 2. Tip of the abdomen of the second instar.
FIG. 3. Tip of the abdomen of the third instar ♀ (female). *1st v,* first pair of valves of ovipositor; *2nd v,* second pair of valves, etc.
FIG. 4. Tip of the abdomen of the third instar ♂ (male).
FIG. 5. Tip of abdomen of fourth instar ♀ (female).
FIG. 6. Tip of the abdomen of the fourth instar ♂.
FIG. 7. Tip of the abdomen of the fifth instar ♀.
FIG. 8. Tip of the abdomen of the fifth instar ♂.
FIG. 9. Ventral view of œdagus.
FIG. 10. Lateral view of œdagus.
FIG. 11. Lateral view of tip of ♂ abdomen.
FIG. 12. Tenth and eleventh tergites with appendages enlarged.

PLATE XXXVII.



♀ 3rd

3



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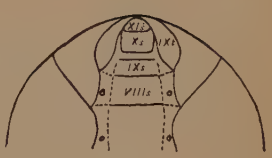
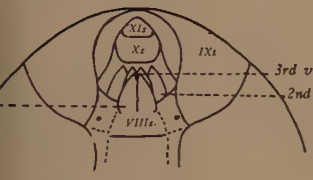


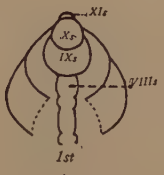
♂ 3rd.

4



♀ 4th

5



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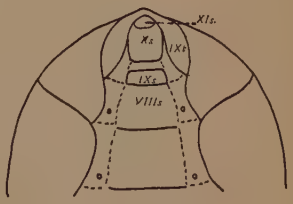
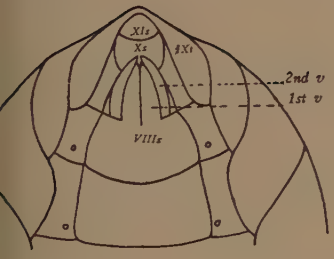


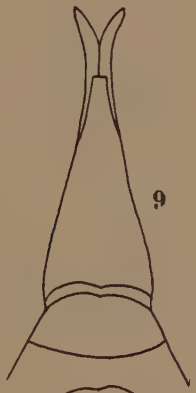
♂ 4th

6



♀ 5th

7



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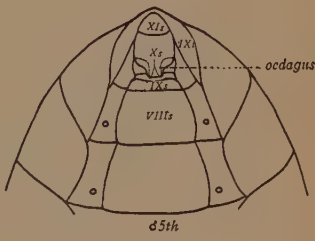
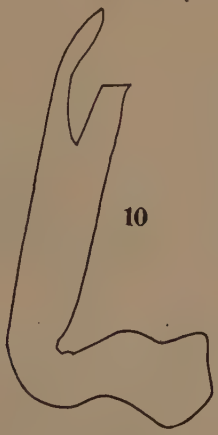


♂ 5th

8

11



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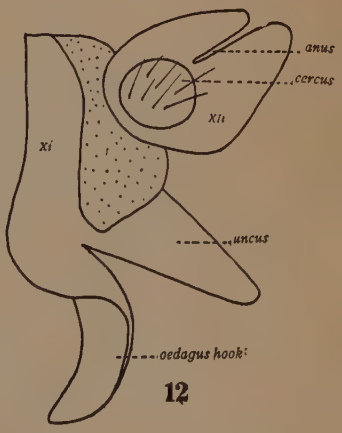


12

PLATE XXXVIII.

FIG. 1. Front legs of the nymphal instars of *Melampsalta calliope* (Walk.) drawn to scale. Note the development of the comb.

FIG. 2. The front legs of all instars and adult of *Cicada hieroglyphica* Say drawn to scale, with the exception of the first, which is larger.

FIG. 3. A nest of *Proarna venosa* (Uhl.) in the dry, fruiting stem of a grass.

FIG. 4. A nest of *Melampsalta calliope* (Walk.) in a stem of sweet clover, showing the fan-shaped arrangement sometimes used.

FIG. 5. Eggs of *Tibicen chloromera* (Walk.) in a dead elm limb. Note the secretion in the outer end of the nest.

FIG. 6. Apex of tibia and tarsi of nymphal instars and adults of *Melampsalta calliope* (Walk.). Note that the first instar has two tarsal segments, the second, third and fourth have but one, the fifth has two, and the adult three. All views of the right hind leg.

FIG. 7. Front leg of the fourth instar nymph of *Melampsalta calliope* (Walk.). (*a*) Femur; (*b*) tibia; (*c*) tarsus; (*d*) comb.

FIG. 8. Front leg of the fifth-instar nymph of *Melampsalta calliope* (Walk.). Lettering same as in Fig. 7.

PLATE XXXVIII.

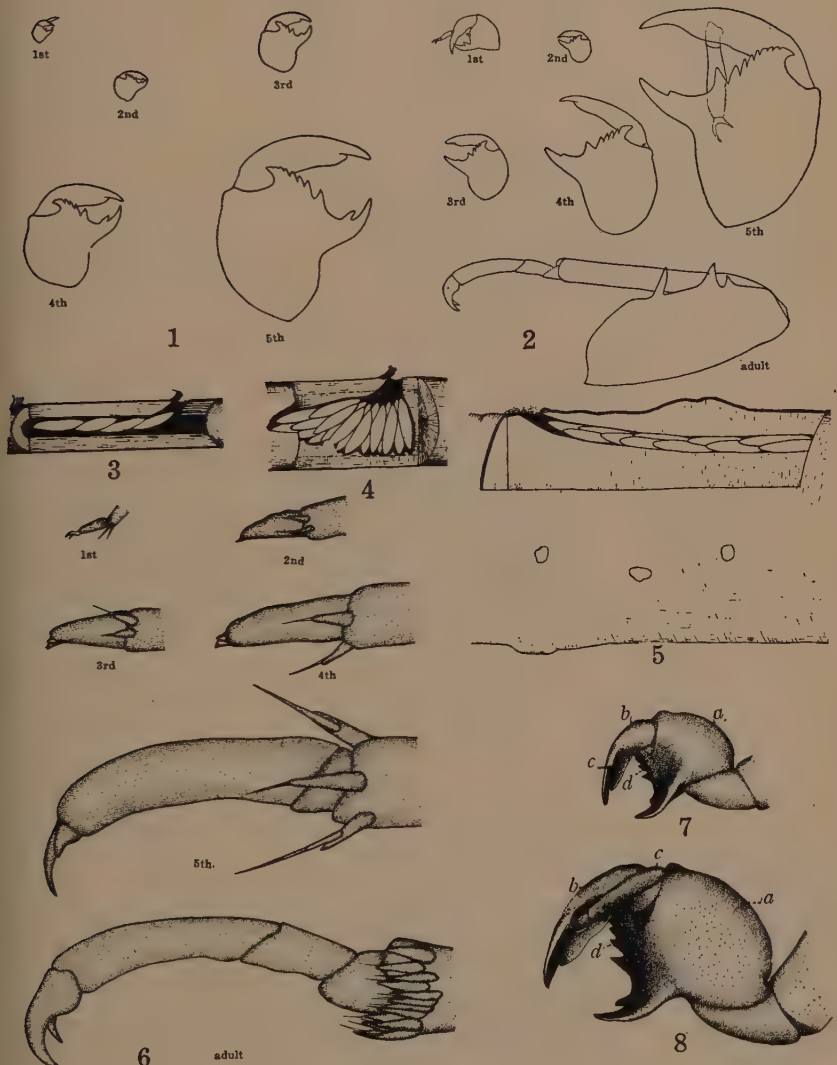


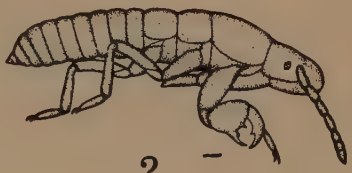
PLATE XXXIX.

Melampsalta calliope.

FIG. 1. Egg × 20.
FIG. 2. First instar × 20.
FIG. 3. Second instar × 10.
FIG. 4. Third instar × 10.
FIG. 5. Fourth instar × 5.
FIG. 6. Fifth instar × 5.
FIG. 7. Adult × 5.

PLATE XXXIX.

5



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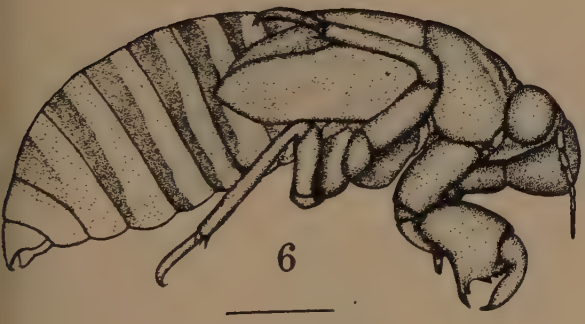

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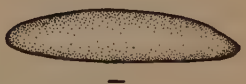

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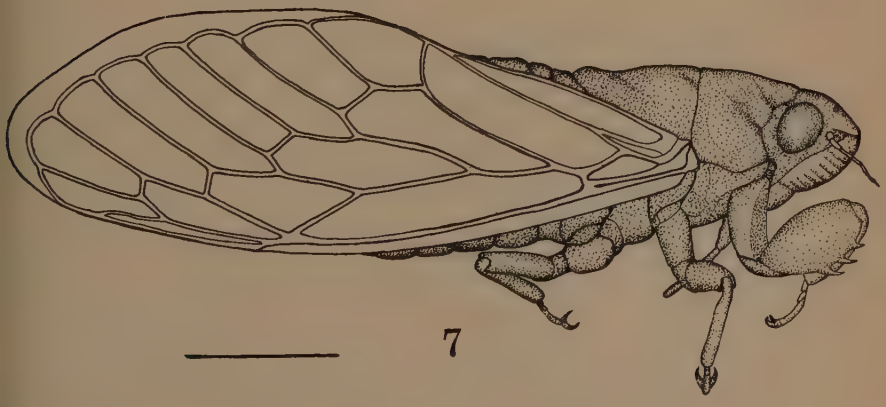

7

PLATE XL.

Proarna venosa (Uhl.)

FIG. 1. The egg × 20.
FIG. 2. First instar × 20.
FIG. 3. Third instar × 8.
FIG. 4. Fourth instar × 8.
FIG. 5. Fifth instar × 5.
FIG. 6. Adult × 5.

PLATE XL.

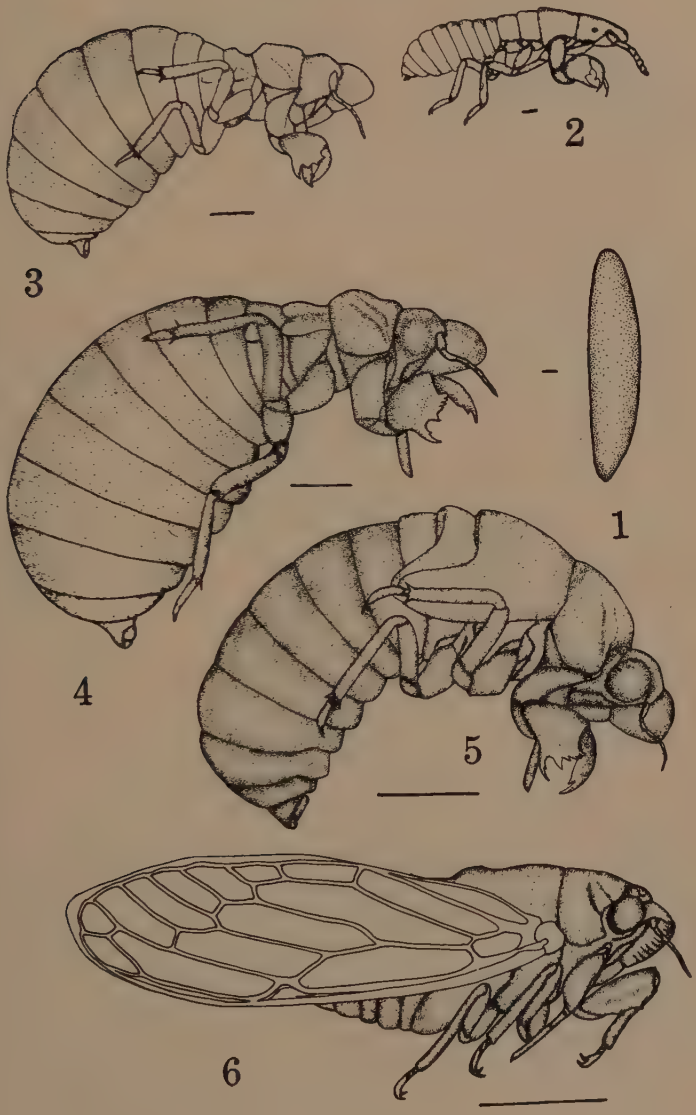

PLATE XLI.

Cicada hieroglyphica Say.

FIG. 1. The egg × 20.
FIG. 2. First instar × 20.
FIG. 3. Second instar × 10.
FIG. 4. Third instar × 8.
FIG. 5. Fourth instar × 5.
FIG. 6. Fifth instar × 5.

PLATE XLI.

4

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2

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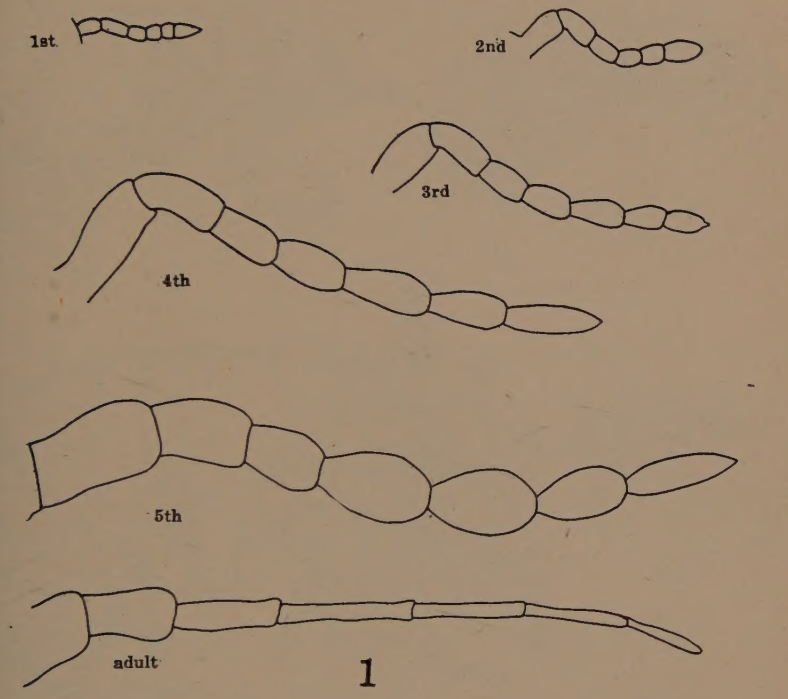
PLATE XLII.

Cicada hieroglyphica Say.

FIG. 1. The antennæ of the nymphal instars and the adult drawn to scale. Note the bulblike tendency of some of the joints of the nymphal antennæ.

FIG. 2. Tip of hind leg of all nymphal instars and adult, showing tarsal segments and setæ-bearing spines as well as the tarsal claws.

PLATE XLII.



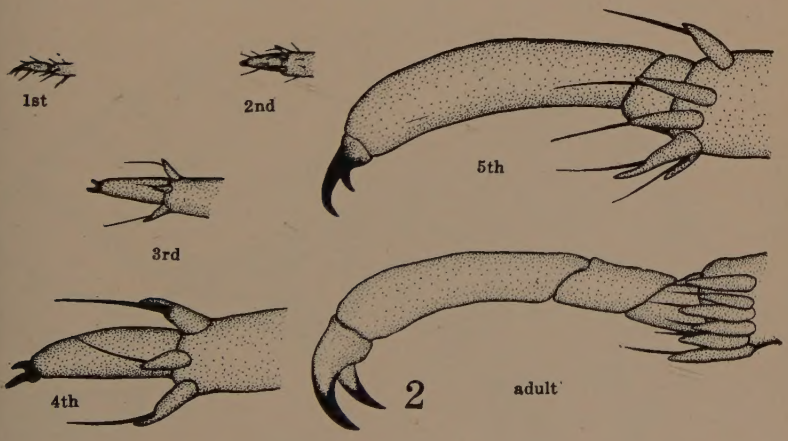
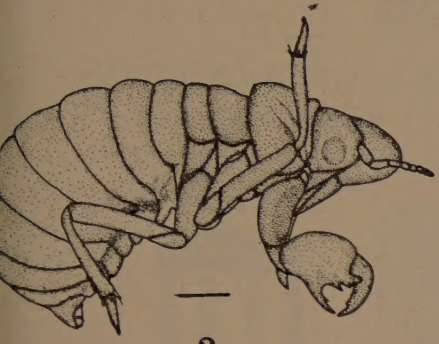


PLATE XLIII.

Tibicen aurifera (Say).

FIG. 1. First instar × 20.
FIG. 2. Second instar × 10.
FIG. 3. Third instar × 8.
FIG. 4. Fourth instar × 5.
FIG. 5. Fifth instar × 5.
FIG. 6. The egg × 20.

PLATE XLIII.



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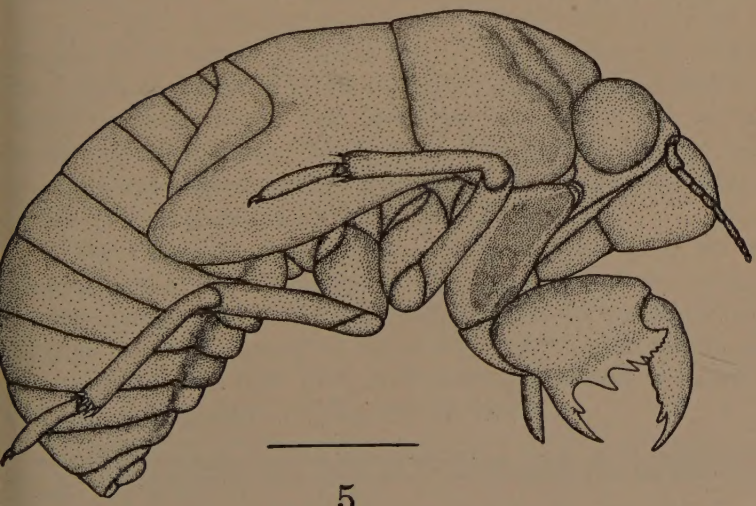

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